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THOMAS HENRY HUXLEY

SELECTED
ESSAYS AND ADDRESSES

OF

THOMAS HENRY HUXLEY

EDITED

WITH NOTES AND AN INTRODUCTION

BY

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McKinley High School, St. Louis, Missouri

New York
THE MACMILLAN COMPANY
1914

Set up and electrotyped. Published May, 1910.
October, 1914.

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

PREFATORY NOTE

In selecting the Essays and Addresses for this volume the editor has desired first of all to give a fair view of the wide field of Huxley's interest. Many of the intellectual conflicts, however, in which he felt called to take part have since his time become almost dead issues. It would be quite out of place to revive them in a book meant largely for class-room use. For the sake of classes of greater maturity and readers who desire to see Huxley's relation to certain philosophical problems, two lectures, *On Descartes' Discourse* and *On the Physical Basis of Life*, have been added. For ordinary class-room purposes they are entirely too speculative, though certain passages stand out as models of perfectly clear exposition. Huxley's clear and logical style is perhaps what makes his work chiefly interesting to-day, and we see it best when he is dealing with what would otherwise appear as abstruse and uninviting.

In the Introduction the editor has purposely refrained from giving a chronological account of Huxley's life, but by means of extracts from his letters and other writings he has attempted to give a picture of the many-sided man. An outline of his life would be too scattered to be attractive and illuminating.

Finally, the editor wishes to acknowledge the courtesy of D. Appleton & Co. for permission to print the essays and addresses from the "Authorized Edition" of which they are the publishers, and to use extracts from the interesting volume, *Life and Letters of Thomas H. Huxley*, by his son, Leonard Huxley.

THE LINDELL,
Lincoln, Nebraska,
July 12, 1909.

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INTRODUCTION

THOMAS HENRY HUXLEY

"He had intellect to comprehend his highest duty distinctly, and force of character to do it; which of us dare ask for a higher summary of his life than that?" These words were written by Huxley to his friend Hooker on the death of Professor Henslow; and they are even more appropriate when they are applied to the life and work of Huxley himself. When we read his life in the *Autobiography*, or the more lengthy memoirs by Sir Michael Foster and P. Chalmers Mitchell, we are impressed by the manifoldness of his activity. Scientist, citizen, educator, lecturer, writer, — he was all these; and upon all the work he did he impressed the peculiar stamp of his individuality. It is perhaps after all Huxley, the man, who is most interesting.

The enormous growth of scientific research and

scientific education since 1860, — for now almost half the time of our students in secondary schools and colleges is taken up with science in one form or other, and they are busy with its method even in literary courses of study, — is in a large measure due to two causes. The first is the doctrine of evolution, which was put upon a scientific basis in 1859 by the publication of Darwin's *Origin of Species*. The second is the unwearied, as he said, "fanatical," insistence by Huxley upon the importance of physical science as an educational agent. This would in itself be cause sufficient for a study of his life and writings. But it is not Huxley the scientist, so much as Huxley the man, that I propose to bring to your acquaintance in this Introduction. His scientific researches and their value must be left to instructors in biology, physiology, or zoölogy. They have been amply recognized. Let us get a knowledge of the man that will illuminate the other spheres of his activity.

The reader who takes up a biography of Huxley, hoping to read accounts of "moving accidents by field or flood," and other such episodes of "a strenuous life," will soon find himself disappointed.

With the one exception of his *Rattlesnake* voyage, and a few comparatively mild trips for his health to Egypt and the Alps, he lived a quiet and uneventful life in or near London, industriously devoting himself to what he felt his duty.

The earlier events in Huxley's life are given so well in the *Autobiography* that it would be quite inappropriate to call attention to them here. One thing is highly suggestive of the dogged persistency with which he followed up any plan he set himself. When a student in London, he selected as his motto Goethe's *Wie das Gestirn*, *Ohne Hast*, *Ohne Rast*,— like the star, without haste, without rest. And this diligent pegging away at an ideal, that at first might seem impossible, was what made him the man he grew to be. Late in life when he was speaking to some medical students at a distribution of prizes, after congratulating the victors, he confessed to "an undercurrent of sympathy for those who have not been successful, for those valiant knights who have been overthrown in their tourney, and have not made their appearance in public," and recounting an earlier failure of his own, he proceeded: —

"I said to myself. 'Never mind; what's the next thing to be done?' And I found that policy of 'never minding' and going on to the next thing to be done, to be the most important of all policies in the conduct of practical life. It does not matter how many tumbles you have in this life, so long as you do not get dirty when you tumble; it is only the people who have to stop to be washed and made clean, who must necessarily lose the race. You learn that which is of inestimable importance — that there are a great many people in the world who are just as clever as you are. You learn to put your trust, by and by, in an economy and frugality of the exercise of your powers, both moral and intellectual; and you very soon find out, if you have not found it out before, that patience and tenacity of purpose are worth more than twice their weight of cleverness."

—*Thomas Henry Huxley*, p. 281.

And this thoroughness counted. It was what made him.

The theories he advocated were seldom popular, and often contrary to the prejudices of many of the best Englishmen, and unless he had been sure of every inch of his ground his life's work might easily have been a failure. But of his work the scientific writer of his life, Mr. Mitchell, says:—

"Looking through his memoirs, written many years ago, the subjects of which have since been handled and rehandled by other writers with new knowledge and with new methods at their disposal, one is struck that all the observations he made have stood their ground. With new facts new generalizations have often been reached, and some of the positions occupied by Huxley have been turned. But what he saw and described had not to be redescribed; the citations he made from the older authorities were always so chosen as to contain the exact gist of the writers. These qualities, admirable in scientific work, became at once admirable and terrible in his controversial writings. His own exactness made him ruthless in exposing any inexactness in his adversaries, and there were few disputants who left an argument with Huxley in an undamaged condition. The consciousness which he had of his own careful methods, added to a natural pugnacity, gave him an intellectual courage of a very high order. As he knew himself to have made sure of his premises, he did not care whither his conclusions might lead him, against whatsoever established doctrine or accepted axiom."

—*Thomas Henry Huxley*, p. 281.

One quotation more, and then we will turn to the details of his life. This desire for thoroughness

made him early hate any form of vacillation. He said on one occasion: —

"A great lawyer, statesman and philosopher of a former age — I mean Francis Bacon — said that truth came out of error much more rapidly than out of confusion. There is a wonderful truth in that saying. Next to being right in this world, the best of all things is to be clearly and definitely wrong, because you will come out somewhere. If you go buzzing about between right and wrong, vibrating and fluctuating, you come out nowhere; but if you are absolutely and thoroughly and persistently wrong, you must, some of these days, have the extreme good fortune of knocking your head against a fact, and that sets you all straight again. So I will not trouble myself as to whether I may be right or wrong in what I am about to say, but at any rate I hope to be clear and definite; and then you will be able to judge for yourselves whether, in following out the train of thought I have to introduce, you knock your heads against facts or not."

— *Thomas Henry Huxley*, p. 280.

Equipped with this fearlessness and persistency, the two noblest attributes of a student, Huxley was ready to take up his life work.

Preparation for Life

The early failure referred to above was at the very outset of his career. While he was attending lectures at Sydenham College, he was urged by his favorite sister to try for a prize medal in Botany. He failed to secure the first prize, but a special medal was granted him for the excellence of his paper.

In 1835 the School at Ealing, where his father was second master, broke up, and the family moved to Coventry. There, in the home of Dr. Cooke, his brother-in-law, young Thomas was first interested in human anatomy. Beyond this growing interest in how living things are made, there is no record of his having been a precocious child. But a boyish journal he began in his fifteenth year shows what he was doing, and in what direction his mind was moving. He called it, in German style, — for he was then reading both French and German, — *Thoughts and Doings;* and prefaced it with a quotation from Novalis: "Philosophy can bake no bread; but it can prove for us God, freedom, and immortality. Which, now, is more practical, — Philosophy or Economy?" And all through his life

this love of the study of philosophy remained. Several times he was twitted by his close friends for dividing his attention between Science and Metaphysics. But it is a safe guess, that had Huxley been less the philosopher, had he lacked that comprehensive outlook on the universe, he would have been less the scientist. His breadth of view and his scientifically accurate mode of thought made him preëminently fit to become, for his age, one of its greatest leaders in thought.

A passage in his journal, dated January 20, 1841, is a good illustration of this early interest in many things.

He has begun German, and Italian; and is working on Latin, Greek, Algebra, Geometry, History, Physiology, Chemistry, Natural Philosophy [Physics], and Grammar. It is interesting to see him at this early age working at German and Italian, studies that were, to say the least, unfamiliar at that time in England. Not a little of his later success he owed to his mastery over foreign languages.

The family decided that they would make a physician of this serious-minded youth. In 1841 he moved to Rotherhithe, near London, as an as-

sistant to a physician, and to walk the hospitals preliminary to going to London for his medical degree. His life near the slums of the great city opened his eyes to the misery of many of his fellow-creatures. Like Dickens, his heart ached to see so much helplessness and suffering. This is what afterward made him the friend of the common people.

After a time at Sydenham College he was admitted to a scholarship in the Charing Cross Hospital; and it was then that his special aptitude became noticeable. He gained prizes, and formed important friendships, so that on his receiving a degree in 1845, and being accepted in the navy as Assistant Surgeon in 1846, he was assigned to special duty on the *Rattlesnake*.

THE *RATTLESNAKE* VOYAGE

It is worth notice that of the chief scientists of the past century, three, Darwin, Hooker, and Huxley, received their first training on one of her Majesty's vessels. We must remember that there were few schools at this time competent to impart even the most rudimentary instruction in

any branch of science; and that what scientific information there was, could, without much difficulty, be placed in a ship's library. The long years of study, and especially of uninterrupted opportunity for investigation, were the best training in the world for acquiring and classifying new facts.

The *Rattlesnake* was gone four years, during which time it visited Madeira, Rio de Janeiro, Cape Town, Mauritius, Hobart Town, Sidney, and the seas east of Australia, and between Australia and Borneo. Thus the observations Huxley made were in the tropical seas, and under conditions most favorable for a young naturalist, who wished to study invertebrate sea life. The voyage had one more effect on his future life. At Sidney he met his future wife, Miss Henrietta Anne Heathorne. It was almost a case of love at first sight. They were not married, however, until 1855, five years after his return to England.

Professor Virchow has written admirably of the effect of this voyage and Huxley's work.

"When Huxley left Charing Cross Hospital in 1846, he had enjoyed a rich measure of instruction in anatomy and physiology. Thus trained, he

took the post of naval surgeon, and by the time that he returned, four years later, he had become a perfect zoölogist and a keen-sighted ethnologist. How this was possible any one will readily understand who knows from his own experience how great the value of personal observation is for the development of independent and unprejudiced thought. For a young man, who, besides collecting a rich treasure of positive knowledge, has practised dissection and the exercise of a critical judgment, a long sea voyage and a peaceful sojourn among entirely new surroundings afford an invaluable opportunity for original work and deep reflection. Freed from the formalism of the schools, thrown upon the use of his own intellect, compelled to test each single object as regards properties and history, he soon forgets the dogmas of the prevailing system and becomes, first a sceptic, and then an investigator. This change, which did not fail to affect Huxley, and through which arose the Huxley whom we commemorate to-day, is no unknown occurrence to one who is acquainted with the history, not only of knowledge, but also of scholars."

The Scientist

Huxley went out on the *Rattlesnake* a young, inexperienced, totally unknown, but enthusiastic

inquirer; he returned matured and with important additions of carefully investigated and classified facts. He was given an immediate recognition by the scientific world, and met on intimate terms all the leading English scientists. A year later he was elected Fellow of the Royal Society, an honor that wealth and position cannot buy; two years later he was awarded the Royal Medal in Physiology, a thing competed for by the leaders in science; and his position as a scientist was secure.

But his trouble now was to get a practical footing that would enable him to marry and pursue his new calling. The squabbles over the expense of printing the results of his four years' investigations, and his growing antipathy to the life in the navy, both spoken of in the *Autobiography*, are but signs on the surface of the difficulties he had in getting settled in his life's work. After he finally cut himself loose from the navy he supported himself by working for the publishers. He wrote reviews and popular scientific articles, translated foreign scientific memoirs, and gave a series of addresses at the Royal Institution. The thing that appears most strange to us to-day is that there was then no

place for a prominent young scientist at any of the universities.

In 1854 he became Naturalist to the Geological Survey, and Lecturer on General Natural History at the Metropolitan School of Science applied to Mining and the Arts. From now on his life was passed mainly in London, with numerous visits to Switzerland on account of his health, and to various parts of the British Islands, on the many Royal Commissions on which he served. About this time, too, he began the series of science lectures to working men and others, which have done so much to popularize the various branches of science. And it was just a little later that be began the movement for scientific instruction in schools and universities that has borne such fruit in our own time.

On the night of January 1, 1857, when his eldest son was born, he wrote: —

"It is impossible to map out beforehand how this must be done. I must seize opportunities as they come, at the risk of the reputation of desultoriness.

"In 1860 I may fairly look forward to fifteen or twenty years 'Meisterjahre,' and with the compre-

hensive views my training will have given me, I think it will be possible in that time to give a new and healthier direction to all Biological Science.

"To smite all humbugs, however big; to give a nobler tone to science; to set an example of abstinence from petty personal controversies, and of toleration for everything but lying; to be indifferent as to whether the work is recognized as mine or not, so long as it is done; — are these my aims? In 1860 will show."

—*Life and Letters*, Vol. I, p. 162.

The Evolution Theory

In 1859 was published Darwin's *Origin of Species*, an epoch not only in science, but in literature and life. The doctrine of evolution has been so well taught since that time that to-day we look upon it as one of the best known and most widely accepted of nature's laws, almost akin in its universality to the laws of gravitation and the conservation of energy. Nor was Darwin the first to promulgate the now well-known doctrine, for it goes back as far as Plato. But what had been before but more or less hazy speculation was now given a scientific basis of experimentation and proof, and was applied

as well to man as to the lowest forms of animal life. This it was that aroused such a storm of protest all over the world that Darwinism became not only a term of reproach, but anathema.

The eighteenth century, the American Revolution, the French Revolution, the doctrine of universal suffrage, the abolition of slavery, the thinking of such men as Rousseau, the poetry of such men as Wordsworth, had all set before the world the worth and dignity of man. Now came this doctrine of evolution which at first sight seemed so to degrade him into whose nostrils God had breathed the breath of life. People were horrified. Carlyle called it the "monkey damnification of mankind," and was never able to forgive its advocate. Even so late as near the end of his life, one day Huxley saw him solitary, walking on the opposite side of the street, and crossed over. Carlyle raised his eyes and said simply, "You are Huxley who thinks that we are descended from monkeys," and passed on. Not only was the doctrine assailed, but even the characters of its advocates. And of these none was more enthusiastic than Huxley. Thus he became a bishop "*in partibus infidelium.*"

But in this stream of abuse he got only what he expected. He wrote to Charles Darwin:—

"I trust you will not allow yourself to be in any way disgusted or annoyed by the considerable abuse and misrepresentation which, unless I greatly mistake, is in store for you. Depend upon it, you have earned the lasting gratitude of all thoughtful men. And as to the curs which will bark and yelp, you must recollect that some of your friends, at any rate, are endowed with an amount of combativeness which (though you have often and justly rebuked it) may stand you in good stead.

"I am sharpening up my claws and beak in readiness."

—*Life and Letters*, Vol. I, p. 189.

Those who are interested can read the account of the meeting of the British Association at Oxford in 1860, when the famous debate on evolution took place. (See *Life and Letters*, Vol. I, or *Thomas Henry Huxley*, by Mitchell, Chap. VII.)

THE NEW EDUCATION

Huxley saw that the only way to combat all this hostility on the part of the unscientific world was to

teach science. He, therefore, became the effective advocate of scientific instruction in all schools, from the primary to the university. In 1870 he became a member of the London School Board. During the two years that he served he constantly advocated a course of study suited to modern conditions. He wanted for the primary schools, above all, physical training, to render the child physically fitted to take part in the struggle for existence; drawing; and singing; domestic science for girls; instruction in reading, writing, and arithmetic, — what he called the tools for acquiring knowledge; elementary training in physical science, — first, observation of the most general phenomena, and an advance from these to the conception of the so-called laws of nature. Nor was this science to be limited to the study of nature, for in addition to it and its laws, or modes of operation, there is the world of man whose laws, as found in society, are no less an object of intelligent analysis and classification, — the laws of society. These are to be studied in their most elementary form, the right and wrong in our actions, in the primary schools ; but are to be more and more an object of complete analysis,

as the child passes through the secondary school to the university. And it may here be said that even now — forty years, nearly, after Huxley first wrote on this subject — we have done very little to realize his ideals on this latter branch of scientific instruction.

Not only did he theorize about scientific instruction, but he, in his classes at the School of Mines, and afterwards at South Kensington, carried out his ideas as best he could with the limited means at his disposal. He first introduced the laboratory method in Biology. He trained classes of teachers in the branches they were to teach; and many a scientific teacher in England to-day got his first inspiration and instruction from Huxley himself. Besides this, he wrote text-books to illustrate his methods.

In 1880 he published his *Science Primer*, and was editor of the numerous *Science Primers*, on Chemistry, Physics, etc., which are used as text-books even to-day, notwithstanding the many advances made since that time, so excellently was the work done. He wrote his *Elementary Lessons in Physiology*, a text-book still used; and later his in-

vestigation of the *Crayfish* as a model of biological examination of a typical crustacean. A scientist says to-day that this is "probably the best biological treatise ever written." Not merely was his aim in this book to see "what are the structures in this animal ? but how, and why do they come to be what they are ?" Knowledge was not to be only a mere acquisition of details, but a mastery of relations.

His idea of an education was as broad as the best ideal to-day : "I conceive it to be our duty to make a ladder from the gutter to the university along which any child may climb." To give the widest and most modern culture he would add German and French, and give these modern languages much of the emphasis which previously had been given to Latin and Greek. He met the objection of the expense of such a training and the incapacity of most students, by saying that no subjects were carried beyond the elementary stage, and that practical ability must be given an opportunity to show itself ; education must be a "capacity catcher."

Along with this education of the young, he energetically advocated the education of the old. I have

mentioned the lectures to working men, and his lectures before the Royal Institution. They were a part of his scheme to give proper things to think about after the day's work was over. He was especially interested in his working men, whose lives were only too frequently passed in the most unwholesome surroundings, physical and mental. An interesting incident is reported of the way the working men returned his interest: —

"I recollect going with him and Mr. John Westlake, Q.C., to a meeting of artisans in the Blackfriars Road, to whom he gave a friendly address. He felt a strong interest in working-men, and was much beloved by them. On one occasion, having taken a cab home, on his arrival there, when he held out his fare to the cabman, the latter replied, "Oh, no, Professor, I have had too much pleasure and profit from hearing you lecture to take any money from your pocket — proud to have driven you, sir!"
— *Life and Letters*, Vol. II, p. 434.

It is no wonder. He once said, "If I am to be remembered at all, I should like to be remembered as one who did his best to help the people."

The general interest in his lectures may be gathered from an article that appeared in the *Spectator*,

December 8, 1877, as follows: "Professor Huxley delivered a very amusing address last Saturday at the Society of Arts, on the very unpromising subject of technical education; but we believe if Professor Huxley were to become the President of the Social Science Association, or of the International Statistical Congress, he would still be amusing, so much bottled life does he infuse into the driest topic on which human beings ever contrived to prose."

It was thus that Huxley educated the English-speaking world in the truths of science, so that what was at first regarded with hostility on all sides has now become as familiar as any scientific hypothesis.

Public Life

I have alluded to Huxley's political duties — the Royal Commissions on which he served. When there is any question before the British government, it has the excellent custom of appointing a Royal Commission who serve as expert advisers of the ministry and parliament. Not a small part of Huxley's time was taken up with such duties. He

served almost continuously on Fisheries Commissions, was a member of the Commissions on Art Instruction for Ireland, the College of Science in Ireland, Contagious Diseases, Scientific Instruction, Vivisection, Universities of Scotland, Medical Acts. Before his death he was sworn a member of the Privy Council, one of the highest political honors in England. He was besides Secretary of the Royal Society from 1871 to 1880 and President from 1883 to 1885, both, while not political offices, involving a great deal of public work. He was on the governing board of several institutions of learning, serving as Lord Rector of Aberdeen (Scotland) University in 1871. All these took a great deal of time, but aided in his grand project of furthering scientific habits of thought and instruction. But they to-day are of much less interest than the picture of the man himself as he lived in the midst of his many activities.

Friends and Family

Among his friends Huxley had many of the chief scientists, literary men, and statesmen of the time; and his letters to such men as Darwin, Hooker,

Sir Michael Foster, Tyndall, Sir Charles Donnelly, Herbert Spencer, the German scientists, Haeckel and Dohrn, the novelist and clergyman, Charles Kingsley, the Marquis of Salisbury, Lord Rosebery, and many others, found in the volumes of his *Life and Letters*, give us a most pleasing picture of the man.

One of the most interesting things in Huxley's life was the foundation in 1864 of the so-called X club. There were nine founders, and no new members were added. It was merely a means whereby these friends and co-workers could get together once a month and enjoy each other's society. There were no by-laws and no officers. It remained intact for nineteen years, until all the members were past middle age, and all had achieved marked success in their several professions. The account of its founding and its members perhaps can best be told in Huxley's own words: —

"Our little club had no very definite object beyond preventing a few men who were united by strong personal sympathies from drifting apart by the pressure of busy lives. . . . Nobody could have foreseen or expected twenty odd years ago, when we first met, that we were destined to play the parts

we have since played, and it is in the nature of things impossible that any of the new members proposed (much as we may like and respect them all) can carry on the work which has so strangely fallen to us."

—*Life and Letters*, Vol. I, p. 281.

Another society of a much wider scope and with a much more definite purpose was founded shortly after — the Metaphysical Society. There was a strong feeling that the claims of religion and the facts of science, which then seemed to be in irreconcilable conflict, ought to find some middle ground of compromise upon which they could both stand. The best men of England — scientists, poets, writers, clergymen — joined, and the meetings at least had one good result: they brought the men into terms of personal friendship. The clergymen who had been so enraged at the Darwinian heresies came to see that the scientists were not a bad set of people after all; and the scientists who had been equally severe on the clergy found that they were honest men with generous convictions. Huxley was one of the most active members. Tennyson was a silent member, who listened and thought. But the new

society "died of too much love." The men learned to love each other, but the doctrines on which they differed were relegated to the background. The reconciliation of science and religion, which we see promised to-day, was then below the horizon. But that a society of such a kind was possible only ten years after the *Origin of Species* was published argued well for the future.

About the same time a Dr. Dohrn, a German naturalist, came to visit the Huxley family,—seven children ranging from ten years to babyhood. The impression left upon him appears from a letter written soon after. "I have to-day been reading several chapters of Mill's *Utilitarianism* and have met the word 'happiness' more than once; if *I* had to give any one a definition of the much-debated word, I should say, 'Go and see the Huxley family at Swanage; and if you would enjoy the same I enjoyed, you would feel what is happiness and nevermore ask for a definition of this sentiment.'"

As a *companion* picture to this, read this birthday letter which Huxley wrote his son in 1878:—

"Your mother reminds me that to-morrow is your eighteenth birthday, and though I know that my 'happy returns' will reach you a few hours too late I cannot but send them.

"You are touching manhood now, my dear laddie, and I trust that as a man your mother and I may always find reason to regard you as we have done throughout your boyhood.

"The great thing in the world is not so much to seek happiness as to earn peace and self-respect. I have not troubled you much with paternal didactics — but that bit is 'ower true' and worth thinking over."

—*Life and Letters*, Vol. I, p. 539.

Travels

In 1872 his health, which had never been robust and which had caused him to spend several summers in Switzerland, gave way entirely. His friends voted him a vacation and raised a considerable fund to send him abroad. He went to Egypt, visited places of interest on the Nile, and then spent some time in Southern Italy. He must have left some impression in the former country, for a visitor coming later to Memphis found that one of the numerous little donkey drivers had named his animal after the professor.

He was charmed with Italy, this time, for a later visit found him in a very different mood. He met friends at Naples and with them climbed Vesuvius, which interested him on account of the scenery as well as on account of its scientific value.

"Egypt interested me profoundly, but I must reserve the tale of all I did and saw there for word of mouth. From Alexandria I went to Messina, and thence made an excursion along the lovely Sicilian coast to Catania and Etna. The old giant was half covered with snow, and this fact, which would have tempted you to go to the top, stopped me. But I went to the Val del Bove, whence all the great lava streams have flowed for the last two centuries, and feasted my eyes with its rugged grandeur. From Messina I came on here, and had the great fortune to find Vesuvius in eruption. Before this fact the vision of good Bence Jones forbidding much exertion vanished into thin air, and on Thursday up I went in company with Ray Lankester and my friend Dohrn's father, Dohrn himself being unluckily away. We had a glorious day, and did not descend until late at night. The great crater was not very active, and contented itself with throwing out great clouds of steam and volleys of red-hot stones now and then. These were thrown toward the southwest of the cone, so that it was practicable to walk

all around the northern and eastern lip, and look down into the Hell Gate. I wished you were there to enjoy the sight as much as I did. No lava was issuing from the great crater, but on the north side of this, a little way below the top, an independent cone had established itself as the most charming little pocket-volcano imaginable. It could not have been more than 100 feet high, and at the top was a crater not more than six or seven feet across. Out of this, with a noise exactly resembling a blast-furnace and a slowly working, high-pressure steam-engine combined, issued a violent torrent of steam and fragments of semi-fluid lava as big as one's fist, and sometimes bigger. These shot up sometimes as much as 100 feet, and then fell down on the sides of the little crater, which could be approached within fifty feet without any danger. As darkness set in, the spectacle was most strange. The fiery stream found a lurid reflection in the slowly drifting steam-cloud, which overhung it, while the red-hot stones which shot through the cloud shone strangely beside the quiet stars in a moonless sky."

— *Life and Letters*, Vol. I, pp. 400–401.

In 1884 the same Naples charmed him no more. Perhaps it was on account of his being in a worse physical condition, perhaps it was increasing age,

perhaps it was only the weather; but he wrote to his youngest daughter, "We are going to Rome to-morrow, having had enough of Naples, the general effect of which city is such as would be produced by the sight of a beautiful woman who had not washed or dressed her hair for a month."

On this second visit even Florence, Milan, and Genoa were not to his liking. His health did not permit much enjoyment of art or scenery. This is his picture of Florence: —

"We have been here more than a week and have discovered two things: first, that the wonderful 'art treasures,' of which all the world has heard, are a sore burden to the conscience if you don't go to see them, and an awful trial to the back and legs if you do; and thirdly, that the climate is productive of a peculiar kind of relaxed throat. M.'s [his wife] throat discovered it, but on inquiry, it proved to be a law of nature, at least, so the oldest inhabitants say.

"But it is a lovely place for all that, far better than Rome as a place to live in, and full of interesting things. We had a morning at the Uffizi the other day, and came back with minds enlarged and backs broken. To-morrow we contemplate attacking the Pitti, and doubt not the result will be similar. By

the end of the week our minds will probably (be) so large and the small of the back so small that we should probably break if we stayed any longer, so think it prudent to be off to Venice."

—*Life and Letters*, Vol. II, pp. 107, 108.

And so he gives a great sigh of thanksgiving when he gets to England again. "We got here this afternoon after a rather shaky passage from Boulogne, with a strong north wind in our teeth all the way, and rain galore. For all that, it is the pleasantest journey I have made for a long time — so pleasant to see one's own dear native mud again. There is no foreign mud to come near it."

In 1876 he visited America. Huxley, as the apostle of veracity, — not so much as the student of science, but as the teacher of men, — had if anything a greater following in America than in England. So we can appreciate the words of an enthusiastic reporter: "The whole nation is electrified by the announcement that Professor Huxley is to visit us next fall. We will make infinitely more of him than we did of the Prince of Wales and his retinue of lords and dukes." And America did justice to this man of science. "His writings had

made him known far and wide; as the manager of the California Department at the Philadelphia Exhibition told him, the very miners of California read his books over their camp-fires; and his visit was so far like a royal progress that unless he entered a city disguised under the name of Jones or Smith, he was liable not merely to be interviewed, but be called upon to address a few words to the citizens."

He went as far west as Nashville, where he met his sister he had not seen for over twenty-five years. His chief lecture was to be delivered at Johns Hopkins University. The sight of this large institution devoted to scientific and literary investigation delighted him. "It has been my fate to see great educational funds fossilize into mere bricks and mortar in the petrifying springs of architecture. A great warrior is said to have made a desert and called it peace. Trustees have sometimes made a palace and called it a University."

The lecture at Baltimore gives another picture of the man and what he stood for.

"I cannot say that I am in the slightest degree impressed by your bigness or your material resources, as such. Size is not grandeur, territory does not

make a nation. The great issue, about which hangs a true sublimity, and the terror of overhanging fate, is, What are you going to do with all these things? . . . The one condition of success, your sole safeguard, is the moral worth and intellectual clearness of the individual citizen. Education cannot give these, but it can cherish them and bring them to the front in whatever station of society they are to be found, and the universities ought to be and may be the fortresses of the higher life of the nation."

—*Life and Letters*, Vol. I, p. 500.

Retirement and Death

But we must hasten over the last things in his life. In 1885, after thirty-one years of continuous service under the government, he was retired with a generous pension. He writes to Sir John Donnelly: "Nevertheless it will be a sad day for me when I find myself no longer entitled to take part in the work of the schools in which you and I have been so long interested."

But his work was by no means over. Though he retired soon after to South Surrey, built himself a home on the chalk downs, and set to work dili-

gently to cultivate a garden, he found that his habits would by no means leave him at peace. "I am sure that the habit of incessant work into which we all drift is as bad in its way as dram drinking. In time you cannot be comfortable without the stimulus." And so he went heart and soul into a long conflict with Gladstone on the scientific basis of the creation story in Genesis. The old fighter enjoyed showing his beak and claws as much in this his last fight as he had in the earlier and more enthusiastic fights over evolution.

His summers he spent in the Alps studying the gentians and taking long walks. In the winter of 1889 he went on a voyage to the Canaries. In May, 1893, he delivered his last lecture, at Oxford, on "Evolution and Ethics." It was his last public appearance. In 1894 he celebrated his scientific triumph by receiving the Darwin Medal from the Royal Society. Early in the spring of 1895 he was taken with influenza. He struggled with a patience and gentleness that astonished his trained nurses. In May he crept out to see his garden, but renal and heart trouble set in and on June 29, 1895, he died.

By special direction the lines from a poem written by his wife were inscribed on his tombstone — lines inspired by his robust conviction that, all questions of the future apart, this life as it can be lived, pain, sorrow, and evil notwithstanding, is worth — and well worth — living: —

> "Be not afraid, ye waiting hearts that weep,
> For still he giveth His beloved sleep,
> And if an endless sleep He wills, so best."

A word on his appearance. He was of middle stature, his face was "grave, black-browed, and fiercely earnest. His hair, plentiful and worn rather long, was black until it became silvery white. His short side-whiskers left exposed an obstinate chin, mobile lips, grim and resolute in repose, but capable of relaxation, with a smile of almost feminine charm." "There was no face, I do believe," wrote Sir Walter Besant, "wiser, more kindly, more beautiful for wisdom, and the kindliness of it, than this of Huxley."

"Truthfulness, in his eyes, was the cardinal virtue, without which no stable society can exist. Clever men, he would say, are as common as blackberries; the rare thing is to find a good one."

He was a scholar — "I have always been, and propose to remain a mere scholar. All that I have ever proposed to myself is to say, this and this have I learned; thus and thus have I learned it: go thou and learn better; but do not thrust on my shoulders the responsibility for your own laziness if you elect to take, on my authority, conclusions, the value of which you ought to have tested for yourself."

And this ideal of scholarship went into his very style of writing. "Say that which has to be said in such language that you can stand cross-examination in each word. Be clear, though you may be convicted of error. If you are clearly wrong, you will run up against a fact sometime and get set right. If you shuffle with your subject, and study chiefly to use language which will give a loophole of escape either way, there is no hope for you." Literature owes him a debt of gratitude for showing that clearness may be found without baldness. "Science and literature," he said, "are not two things, but two sides of one thing." But Huxley is almost the only scientist whose writings won him eminence in both spheres. It is the perfect adaptation of sense and language that makes his works so readable.

HUXLEY'S WORKS

Aside from his purely scientific works, which are mentioned at length in the appendix to his *Life and Letters* by his son, Leonard Huxley, and which do not concern us here, his chief essays and addresses are collected into nine volumes under the title *Collected Essays*, and published by D. Appleton & Co., New York. They are as follows:—

1. Methods and Results.
2. Darwiniana.
3. Science and Education.
4. Science and Hebrew Tradition.
5. Science and Christian Tradition.
6. Hume.
7. Man's Place in Nature.
8. Discourses Biological and Geological.
9. Evolution and Ethics, and Other Essays.

PRACTICAL HINTS FOR THE STUDENT OF HUXLEY'S ESSAYS

The student of Huxley's essays will be interested quite as much in his style as in his subject-matter. While the latter is, as a general rule, interesting even to an unscientific reader, it is the clearness and precision of the ideas that raises it above the average run of scientific writing. So much is this true that Huxley's style has become the model of all writing where clearness and precision are the objects chiefly to be sought for. In examining an essay of his, therefore, for the method by which he secures this result we should keep several things carefully in mind.

First, each work was written primarily for some definite audience, whose mental equipment he had carefully gauged before he began to write. Thus, the address on a *Piece of Chalk* was intended for an audience of working men, whose technical knowledge of the subject was small. He carefully, therefore, selects his materials from things that are known to them, and then proceeds, step by step, to lead them to results of which they had never

dreamed.. But each step in the process is perfectly clear. On the other hand, in his lecture on the *Physical Basis of Life*, he is writing for a cultivated audience in Edinburgh, the most cultivated city in Great Britain. The result is that he can presuppose a considerable familiarity with many subjects of which the working men of his *Piece of Chalk* lecture would be entirely ignorant. He can there quote Hume and other writers with perfect impunity. A striking point of similarity between both lectures is, however, the almost total lack of scientific knowledge he presupposes in both audiences. This was due to the general lack of scientific education in Great Britain. Huxley was careful not to shoot over the heads of his auditors.

In the second place, Huxley was perfectly familiar with every subject he handled. This was to him the secret of clear exposition. He knew what he was writing about. Therefore, he was able to hold up his subject in every possible light, and illustrate it with every possible variety of illustration needed. He enables us to see around a subject, because he has first seen it from every point of view.

This knowledge of his subject enabled him to arrange his material according to a well-developed plan. To the structure of each of his essays and addresses is due not the least part of its clearness. If the reader will take the pains, as by all means he should, to construct their outlines, he will find how intimate is the grouping of the ideas, and how perfectly balanced their structure. Apparent diversions are not afterthoughts, but definite illustrations or strengthening of his argument. There is nothing haphazard in his work.

This care in structure extends even to his paragraphs and sentences. The topics of the former are usually given at the very outset. The relations of paragraphs to paragraphs are continually made unmistakable. The sentences are so constructed and arranged that a single reading gives the thought at once. Spencer, in his essay on Style, evidently had his friend Huxley in mind when he exhorted writers to economize their readers' attention. If we have to work out an author's thoughts by reading and rereading his sentences, when he might have put them more clearly, we waste just so much of our own effort. Huxley's sentences are meant to carry

his thoughts as clearly as possible, no more, — not, as in many more artistic writers, to call attention to themselves. The same is true with his paragraphs. For this reason we shall look in vain for the great variety of paragraph and sentence structure which we find in the works of Macaulay and Newman. But we shall find perfect clearness.

In the choice of his words, too, he worked with the same end in view. He usually prefers the short and simple word to the lengthy and sonorous. When he has to use an unusual word, he stops to define it carefully, instead of sending us off to the dictionary. This was chiefly due to the fact that most of his works were first orally delivered, when dictionary aid was impossible. But even when he uses a simple word, that might bring up ideas he wishes to exclude, he carefully defines its meaning in the passage. He uses words to make his meaning clear and precise, just as a demonstrator in science uses his scientific apparatus, and he exercises the same caution in the choice.

Finally, he arouses our interest, not only by the interest the subjects, if clearly presented, possess, but by his evident sincerity and his personal interest

in them. It is a well-known fact that we cannot interest a person in a subject for which we care little or nothing. It is the sincerity of our interest that is the loadstone that will draw to us the interest of our readers or hearers. The remark that "the style is the man" has often been made, but it has never been better illustrated than by Huxley. Directness and clearness were to him the law and the gospel of thought, and his style, like himself, is direct and clear.

SELECTED ESSAYS AND ADDRESSES

I

AUTOBIOGRAPHY

And when I consider, in one view, the many things . . . which I have upon my hands, I feel the burlesque of being employed in this manner at my time of life. But, in another view, and taking in all circumstances, these things, as trifling as they may appear, no less than things of greater importance, seem to be put upon me to do. . . . — *Bishop Butler*° *to the Duchess of Somerset.*

The "many things" to which the Duchess's correspondent here refers are the repairs and improvements of the episcopal seat at Auckland.° I doubt if the great apologist, greater in nothing than in the simple dignity of his character, would have considered the writing an account of himself as a thing which could be put upon him to do what-

ever circumstances might be taken in. But the good bishop lived in an age when a man might write books and yet be permitted to keep his private existence to himself; in the pre-Boswellian° epoch, when the germ of the photographer lay in the womb of the distant future, and the interviewer who pervades our age was an unforeseen, indeed unimaginable, birth of time.

At present, the most convinced believer in the aphorism "*Bene qui latuit, bene vixit*,"° is not always able to act up to it. An importunate person informs him that his portrait is about to be published and will be accompanied by a biography which the importunate person proposes to write. The sufferer knows what that means; either he undertakes to revise the "biography" or he does not. In the former case, he makes himself responsible; in the latter, he allows the publication of a mass of more or less fulsome inaccuracies for which he will be held responsible by those who are familiar with the prevalent art of self-advertisement. On the whole, it may be better to get over the "burlesque of being employed in this manner" and do the thing himself.

It was by reflections of this kind that, some years

ago, I was led to write and permit the publication of the subjoined sketch.

I was born about eight o'clock in the morning on the 4th of May, 1825, at Ealing, which was, at that time, as quiet a little country village as could be found within half-a-dozen miles of Hyde Park Corner.° Now it is a suburb of London with, I believe, 30,000 inhabitants. My father was one of the masters in a large semi-public school which at one time had a high reputation. I am not aware that any portents preceded my arrival in this world, but, in my childhood, I remember hearing a traditional account of the manner in which I lost the chance of an endowment of great practical value. The windows of my mother's room were open, in consequence of the unusual warmth of the weather. For the same reason, probably, a neighbouring beehive had swarmed, and the new colony, pitching on the window-sill, was making its way into the room when the horrified nurse shut down the sash. If that well-meaning woman had only abstained from her ill-timed interference, the swarm might have settled on my lips, and I should have been endowed

with that mellifluous eloquence which, in this country, leads far more surely than worth, capacity, or honest work, to the highest places in Church and State. But the opportunity was lost, and I have been obliged to content myself through life with saying what I mean in the plainest of plain language, than which, I suppose, there is no habit more ruinous to a man's prospects of advancement.

Why I was christened Thomas Henry I do not know; but it is a curious chance that my parents should have fixed for my usual denomination upon the name of that particular Apostle° with whom I have always felt most sympathy. Physically and mentally I am the son of my mother so completely — even down to peculiar movements of the hands, which made their appearance in me as I reached the age she had when I noticed them — that I can hardly find any trace of my father in myself, except an inborn faculty for drawing,° which unfortunately, in my case, has never been cultivated, a hot temper, and that amount of tenacity of purpose which unfriendly observers sometimes call obstinacy.

My mother was a slender brunette, of an emo-

tional and energetic temperament, and possessed of the most piercing black eyes I ever saw in a woman's head. With no more education than other women of the middle classes in her day, she had an excellent mental capacity. Her most distinguishing characteristic, however, was rapidity of thought. If one ventured to suggest she had not taken much time to arrive at any conclusion, she would say, "I cannot help it, things flash across me." That peculiarity has been passed on to me in full strength; it has often stood me in good stead; it has sometimes played me sad tricks, and it has always been a danger. But, after all, if my time were to come over again, there is nothing I would less willingly part with than my inheritance of mother wit.

I have next to nothing to say about my childhood. In later years my mother, looking at me almost reproachfully, would sometimes say, "Ah! you were such a pretty boy!" whence I had no difficulty in concluding that I had not fulfilled my early promise in the matter of looks. In fact, I have a distinct recollection of certain curls of which I was vain, and of a conviction that I closely resem-

bled that handsome, courtly gentleman, Sir Herbert Oakley, who was vicar of our parish, and who was as a god to us country folk, because he was occasionally visited by the then Prince George of Cambridge. I remember turning my pinafore wrong side forwards in order to represent a surplice, and preaching to my mother's maids in the kitchen as nearly as possible in Sir Herbert's manner one Sunday morning when the rest of the family were at church. That is the earliest indication I can call to mind of the strong clerical affinities which my friend Mr. Herbert Spencer° has always ascribed to me, though I fancy they have for the most part remained in a latent state.

My regular school training was of the briefest, perhaps fortunately, for though my way of life has made me acquainted with all sorts and conditions of men, from the highest to the lowest, I deliberately affirm that the society I fell into at school was the worst I have ever known. We boys were average lads, with much the same inherent capacity for good and evil as any others; but the people who were set over us cared about as much for our intellectual and moral welfare as if they were baby-farmers.

We were left to the operation of the struggle for existence among ourselves, and bullying was the least of the ill practices current among us. Almost the only cheerful reminiscence in connection with the place which arises in my mind is that of a battle I had with one of my classmates, who had bullied me until I could stand it no longer. I was a very slight lad, but there was a wild-cat element in me which, when roused, made up for lack of weight, and I licked my adversary effectually. However, one of my first experiences of the extremely rough-and-ready nature of justice, as exhibited by the course of things in general, arose out of the fact that I — the victor — had a black eye, while he — the vanquished — had none, so that I got into disgrace and he did not. We made it up, and thereafter I was unmolested. One of the greatest shocks I ever received in my life was to be told a dozen years afterwards by the groom who brought me my horse in a stable-yard in Sydney° that he was my quondam antagonist. He had a long story of family misfortune to account for his position, but at that time it was necessary to deal very cautiously with mysterious strangers in New South

Wales, and on inquiry I found that the unfortunate young man had not only been "sent out," but had undergone more than one colonial conviction.

As I grew older, my great desire was to be a mechanical engineer, but the fates were against this and, while very young, I commenced the study of medicine under a medical brother-in-law. But, though the Institute of Mechanical Engineers would certainly not own me, I am not sure that I have not all along been a sort of mechanical engineer *in partibus infidelium.*° I am now occasionally horrified to think how very little I ever knew or cared about medicine as the art of healing. The only part of my professional course which really and deeply interested me was physiology, which is the mechanical engineering of living machines; and, notwithstanding that natural science has been my proper business, I am afraid there is very little of the genuine naturalist in me. I never collected anything, and species work was always a burden to me; what I cared for was the architectural and engineering part of the business, the working out the wonderful unity of plan in the thousands and thousands of diverse living constructions, and the

modifications of similar apparatuses to serve diverse ends. The extraordinary attraction I felt towards the study of the intricacies of living structure nearly proved fatal to me at the outset. I was a mere boy — I think between thirteen and fourteen years of age — when I was taken by some older student friends of mine to the first *post-mortem* examination I ever attended. All my life I have been most unfortunately sensitive to the disagreeables which attend anatomical pursuits, but on this occasion my curiosity overpowered all other feelings, and I spent two or three hours in gratifying it. I did not cut myself, and none of the ordinary symptoms of dissection-poison supervened, but poisoned I was somehow, and I remember sinking into a strange state of apathy. By way of a last chance, I was sent to the care of some good, kind people, friends of my father's, who lived in a farm-house in the heart of Warwickshire. I remember staggering from my bed to the window on the bright spring morning after my arrival, and throwing open the casement. Life seemed to come back on the wings of the breeze, and to this day the faint odour of wood-smoke, like that which floated

across the farm-yard in the early morning, is as good to me as the "sweet south upon a bed of violets°." I soon recovered, but for years I suffered from occasional paroxysms of internal pain, and from that time my constant friend, hypochondriacal dyspepsia,° commenced his half century of co-tenancy of my fleshly tabernacle.

Looking back on my "Lehrjahre,"° I am sorry to say that I do not think that any account of my doings as a student would tend to edification. In fact, I should distinctly warn ingenuous youth to avoid imitating my example. I worked extremely hard when it pleased me, and when it did not — which was a very frequent case — I was extremely idle (unless making caricatures of one's pastors and masters is to be called a branch of industry), or else wasted my energies in wrong directions. I read everything I could lay hands upon, including novels, and took up all sorts of pursuits to drop them again quite as speedily. No doubt it was very largely my own fault, but the only instruction from which I ever obtained the proper effect of education was that which I received from Mr. Wharton Jones,° who was the lecturer on physiology at the Charing Cross School of Medi-

cine. The extent and precision of his knowledge impressed me greatly, and the severe exactness of his method of lecturing was quite to my taste. I do not know that I have ever felt so much respect for anybody as a teacher before or since. I worked hard to obtain his approbation,° and he was extremely kind and helpful to the youngster who, I am afraid, took up more of his time than he had any right to do. It was he who suggested the publication of my first scientific paper — a very little one — in the *Medical Gazette* of 1845, and most kindly corrected the literary faults which abounded in it, short as it was; for at that time, and for many years afterwards, I detested the trouble of writing, and would take no pains over it.

It was in the early spring of 1846, that, having finished my obligatory medical studies and passed the first M.B. examination at the London University — though I was still too young to qualify at the College of Surgeons — I was talking to a fellow-student (the present eminent physician, Sir Joseph Fayrer), and wondering what I should do to meet the imperative necessity for earning my own bread, when my friend suggested that I should write to

Sir William Burnett, at that time Director-General for the Medical Service of the Navy, for an appointment. I thought this rather a strong thing to do, as Sir William was personally unknown to me, but my cheery friend would not listen to my scruples, so I went to my lodgings and wrote the best letter I could devise. A few days afterwards I received the usual official circular of acknowledgment, but at the bottom there was written an instruction to call at Somerset House° on such a day. I thought that looked like business, so at the appointed time I called and sent in my card, while I waited in Sir William's ante-room. He was a tall, shrewd-looking old gentleman, with a broad Scotch accent — and I think I see him now as he entered with my card in his hand. The first thing he did was to return it, with the frugal reminder that I should probably find it useful on some other occasion. The second was to ask whether I was an Irishman. I suppose the air of modesty about my appeal must have struck him. I satisfied the Director-General that I was English to the backbone, and he made some inquiries as to my student career, finally desiring me to hold myself ready for examination. Having

passed this, I was in Her Majesty's Service, and entered on the books of Nelson's° old ship, the *Victory*,° for duty at Haslar Hospital, about a couple of months after I made my application.

My official chief at Haslar was a very remarkable person, the late Sir John Richardson,° an excellent naturalist, and far-famed as an indomitable Arctic traveller. He was a silent, reserved man, outside the circle of his family and intimates; and, having a full share of youthful vanity, I was extremely disgusted to find that "Old John," as we irreverent youngsters called him, took not the slightest notice of my worshipful self, either the first time I attended him, as it was my duty to do, or for some weeks afterwards. I am afraid to think of the lengths to which my tongue may have run on the subject of the churlishness of the chief, who was, in truth, one of the kindest-hearted and most considerate of men. But one day, as I was crossing the hospital square, Sir John stopped me, and heaped coals of fire on my head by telling me that he had tried to get me one of the resident appointments, much coveted by the assistant-surgeons, but that the Admiralty had put in another

man. "However," said he, "I mean to keep you here till I can get you something you will like," and turned upon his heel without waiting for the thanks I stammered out. That explained how it was I had not been packed off to the West Coast of Africa like some of my juniors, and why, eventually, I remained altogether seven months at Haslar.

After a long interval, during which "Old John" ignored my existence almost as completely as before, he stopped me again as we met in a casual way, and describing the service on which the *Rattlesnake* was likely to be employed, said that Captain Owen Stanley, who was to command the ship, had asked him to recommend an assistant-surgeon who knew something of science; would I like that? Of course I jumped at the offer. "Very well, I give you leave; go to London at once and see Captain Stanley." I went, saw my future commander, who was very civil to me, and promised to ask that I should be appointed to his ship, as in due time I was. It is a singular thing that, during the few months of my stay at Haslar, I had among my messmates two future Directors-General of the Medical Service of the Navy (Sir Alexander Armstrong and

Sir John Watt-Reid), with the present President of the College of Physicians and my kindest of doctors, Sir Andrew Clark.

Life on board Her Majesty's ships in those days was a very different affair from what it is now, and ours was exceptionally rough, as we were often many months without receiving letters or seeing any civilized people but ourselves. In exchange, we had the interest of being about the last voyagers, I suppose, to whom it could be possible to meet with people who knew nothing of fire-arms — as we did on the South Coast of New Guinea — and of making acquaintance with a variety of interesting savage and semi-civilized people. But, apart from experience of this kind and the opportunities offered for scientific work, to me, personally, the cruise was extremely valuable. It was good for me to live under sharp discipline; to be down on the realities of existence by living on bare necessaries; to find out how extremely well worth living life seemed to be when one woke up from a night's rest on a soft plank, with the sky for canopy and cocoa and weevilly biscuit the sole prospect for breakfast; and, more especially, to learn to work for the sake of what

I got for myself out of it, even if it all went to the bottom and I along with it. My brother officers were as good fellows as sailors ought to be and generally are, but, naturally, they neither knew nor cared anything about my pursuits, nor understood why I should be so zealous in pursuit of the objects which my friends, the middies, christened "Buffons," after the title conspicuous on a volume of the "Suites à Buffon,"° which stood on my shelf in the chart room.

During the four years of our absence,° I sent home communication after communication to the "Linnean Society,"° with the same result as that obtained by Noah when he sent the raven out of his ark. Tired at last of hearing nothing about them, I determined to do or die, and in 1849 I drew up a more elaborate paper and forwarded it to the Royal Society.° This was my dove, if I had only known it. But owing to the movements of the ship, I heard nothing of that either until my return to England in the latter end of the year 1850, when I found that it was printed and published, and that a huge packet of separate copies awaited me. When I hear some of my young

friends complain of want of sympathy and encouragement, I am inclined to think that my naval life was not the least valuable part of my education.°

Three years after my return were occupied by a battle between my scientific friends on the one hand and the Admiralty on the other, as to whether the latter ought, or ought not, to act up to the spirit of a pledge they had given to encourage officers who had done scientific work by contributing to the expense of publishing mine. At last the Admiralty, getting tired, I suppose, cut short the discussion by ordering me to join a ship, which thing I declined to do, and as Rastignac, in the Père Goriot,° says to Paris, I said to London "*à nous deux.*"° I desired to obtain a Professorship of either Physiology or Comparative Anatomy, and as vacancies occurred I applied, but in vain. My friend, Professor Tyndall,° and I were candidates at the same time, he for the Chair of Physics and I for that of Natural History in the University of Toronto, which, fortunately, as it turned out, would not look at either of us. I say fortunately, not from any lack of respect for Toronto, but because I soon made up my mind that London was the

place for me, and hence I have steadily declined the inducements to leave it, which have at various times been offered. At last, in 1854, on the translation of my warm friend, Edward Forbes,° to Edinburgh, Sir Henry De la Beche, the Director-General of the Geological Survey, offered me the post Forbes vacated of Paleontologist° and Lecturer on Natural History. I refused the former point blank, and accepted the latter only provisionally, telling Sir Henry that I did not care for fossils, and that I should give up Natural History as soon as I could get a physiological post. But I held the office for thirty-one years, and a large part of my work has been paleontological.

At that time I disliked public speaking,° and had a firm conviction that I should break down every time I opened my mouth. I believe I had every fault a speaker could have (except talking at random or indulging in rhetoric), when I spoke to the first important audience I ever addressed, on a Friday evening at the Royal Institution, in 1852.° Yet, I must confess to having been guilty, *malgré moi*,° of as much public speaking as most of my contemporaries, and for the last ten years it ceased

to be so much of a bugbear to me. I used to pity myself for having to go through this training, but I am now more disposed to compassionate the unfortunate audiences, especially my ever-friendly hearers at the Royal Institution,° who were the subjects of my oratorical experiments.

The last thing that it would be proper for me to do would be to speak of the work of my life, or to say at the end of the day whether I think I have earned my wages or not. Men are said to be partial judges of themselves. Young men may be, I doubt if old men are. Life seems terribly foreshortened as they look back, and the mountain they set themselves to climb in youth turns out to be a mere spur of immeasurably higher ranges when, with failing breath, they reach the top. But if I may speak of the objects I have had more or less definitely in view since I began the ascent of my hillock, they are briefly these: To promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life to the best of my ability, in the conviction which has grown with my growth and strengthened with my strength, that

there is no alleviation for the sufferings of mankind except veracity of thought and of action, and the resolute facing of the world as it is when the garment of make-believe by which pious hands have hidden its uglier features is stripped off.

It is with this intent that I have subordinated any reasonable, or unreasonable, ambition for scientific fame° which I may have permitted myself to entertain to other ends; to the popularization of science; ° to the development and organization of scientific education; ° to the endless series of battles and skirmishes over evolution; ° and to untiring opposition to that ecclesiastical spirit, that clericalism, which in England, as everywhere else, and to whatever denomination it may belong, is the deadly enemy of science.

In striving for the attainment of these objects, I have been but one among many, and I shall be well content to be remembered, or even not remembered, as such. Circumstances, among which I am proud to reckon the devoted kindness of many friends, have led to my occupation of various prominent positions, among which the Presidency of the Royal Society° is the highest. It would be

mock modesty on my part, with these and other scientific honours which have been bestowed upon me, to pretend that I have not succeeded in the career which I have followed, rather because I was driven into it than of my own free will; but I am afraid I should not count even these things as marks of success if I could not hope that I had somewhat helped that movement of opinion which has been called the New Reformation.°

II

ON THE ADVISABLENESS OF IMPROVING NATURAL KNOWLEDGE

[1866]

THIS time two hundred years ago — in the beginning of January, 1666 — those of our forefathers who inhabited this great and ancient city, took breath between the shocks of two fearful calamities: one not quite past, although its fury had abated; the other to come.

Within a few yards of the very spot on which we are assembled, so the tradition runs, that painful and deadly malady, the plague,° appeared in the latter months of 1664; and, though no new visitor, smote the people of England, and especially of her capital, with a violence unknown before, in the course of the following year. The hand of a master has pictured what happened in those dis-

mal months; and in that truest of fictions, "The History of the Plague Year," Defoe° shows death, with every accompaniment of pain and terror, stalking through the narrow streets of old London, and changing their busy hum into a silence broken only by the wailing of the mourners of fifty thousand dead; by the woful denunciations and mad prayers of fanatics; and by the madder yells of despairing profligates.

But, about this time in 1666, the death-rate had sunk to nearly its ordinary amount; a case of plague occurred only here and there, and the richer citizens who had flown from the pest had returned to their dwellings. The remnant of the people began to toil at the accustomed round of duty, or of pleasure; and the stream of city life bid fair to flow back along its old bed, with renewed and uninterrupted vigour.

The newly kindled hope was deceitful. The great plague, indeed, returned no more; but what it had done for the Londoners, the great fire, which broke out in the autumn of 1666, did for London; and, in September of that year, a heap of ashes and the indestructible energy of the people

were all that remained of the glory of five-sixths of the city within the walls.°

Our forefathers had their own ways of accounting for each of these calamities. They submitted to the plague in humility and in penitence, for they believed it to be the judgment of God. But, towards the fire they were furiously indignant, interpreting it as the effect of the malice of man, — as the work of the Republicans,° or of the Papists,° according as their prepossessions ran in favour of loyalty or of Puritanism.

It would, I fancy, have fared but ill with one who, standing where I now stand, in what was then a thickly peopled and fashionable part of London, should have broached to our ancestors the doctrine which I now propound to you — that all their hypotheses were alike wrong; that the plague was no more, in their sense, Divine judgment, than the fire was the work of any political, or of any religious, sect; but that they were themselves the authors of both plague and fire, and that they must look to themselves to prevent the recurrence of calamities, to all appearance so peculiarly

beyond the reach of human control — so evidently the result of the wrath of God, or of the craft and subtlety of an enemy.

And one may picture to one's self how harmoniously the holy cursing of the Puritan of that day would have chimed in with the unholy cursing and the crackling wit of the Rochesters° and Sedleys,° and with the revilings of the political fanatics, if my imaginary plain dealer had gone on to say that, if the return of such misfortunes were ever rendered impossible, it would not be in virtue of the victory of the faith of Laud,° or of that of Milton°; and, as little, by the triumph of republicanism, as by that of monarchy. But that the one thing needful for compassing this end was, that the people of England should second the efforts of an insignificant corporation, the establishment of which, a few years before the epoch of the great plague and the great fire, had been as little noticed, as they were conspicuous.

Some twenty years before the outbreak of the plague a few calm and thoughtful students banded themselves together for the purpose, as they phrased

it, of "improving natural knowledge." The ends they proposed to attain cannot be stated more clearly than in the words of one of the founders of the organization: —

"Our business was (precluding matters of theology and state affairs) to discourse and consider of philosophical inquiries, and such as related thereunto: — as Physick, Anatomy, Geometry, Astronomy,° Navigation, Staticks, Magneticks, Chymicks, Mechanicks, and Natural Experiments; with the state of these studies and their cultivation at home and abroad. We then discoursed of the circulation of the blood, the valves in the veins, the venæ lacteæ, the lymphatic vessels, the Copernican hypothesis,° the nature of comets and new stars, the satellites of Jupiter, the oval shape (as it then appeared) of Saturn, the spots on the sun and its turning on its own axis, the inequalities and selenography of the moon, the several phases of Venus and Mercury, the improvement of telescopes and grinding of glasses for that purpose, the weight of air, the possibility or impossibility of vacuities and nature's abhorrence thereof, the Torricellian° experiment in quicksilver, the descent of heavy bodies and the degree

of acceleration therein, with divers other things of like nature, some of which were then but new discoveries, and others not so generally known and embraced as now they are; with other things appertaining to what hath been called the New Philosophy, which from the times of Galileo° at Florence, and Sir Francis Bacon° (Lord Verulam) in England, hath been much cultivated in Italy, France, Germany, and other parts abroad, as well as with us in England."

The learned Dr. Wallis,° writing in 1696, narrates in these words, what happened half a century before, or about 1645. The associates met at Oxford, in the rooms of Dr. Wilkins,° who was destined to become a bishop; and subsequently coming together in London, they attracted the notice of the king. And it is a strange evidence of the taste for knowledge which the most obviously worthless of the Stuarts shared with his father and grandfather, that Charles the Second° was not content with saying witty things about his philosophers, but did wise things with regard to them. For he not only bestowed upon them such attention as he could spare from his poodles and his mistresses, but,

being in his usual state of impecuniosity, begged for them of the Duke of Ormond; and, that step being without effect, gave them Chelsea College,° a charter, and a mace; crowning his favours in the best way they could be crowned, by burdening them no further with royal patronage or state interference.

Thus it was that the half-dozen young men, studious of the "New Philosophy," who met in one another's lodgings in Oxford or in London, in the middle of the seventeenth century, grew in numerical and in real strength, until, in its latter part, the "Royal Society for the Improvement of Natural Knowledge" had already become famous, and had acquired a claim upon the veneration of Englishmen, which it has ever since retained, as the principal focus of scientific activity in our islands, and the chief champion of the cause it was formed to support.

It was by the aid of the Royal Society that Newton° published his *Principia*. If all the books in the world, except the "Philosophical Transactions," were destroyed, it is safe to say that the foundations of physical science would remain

unshaken, and that the vast intellectual progress of the last two centuries would be largely, though incompletely, recorded. Nor have any signs of halting or of decrepitude manifested themselves in our own times. As in Dr. Wallis's days, so in these, "our business is, precluding theology and state affairs, to discourse and consider of philosophical inquiries." But our "Mathematick" is one which Newton would have to go to school to learn; our "Staticks, Mechanicks, Magneticks, Chymicks, and Natural Experiments" constitute a mass of physical and chemical knowledge, a glimpse at which would compensate Galileo for the doings of a score of inquisitorial cardinals; our "Physick" and "Anatomy" have embraced such infinite varieties of being, have laid open such new worlds in time and space, have grappled, not unsuccessfully, with such complex problems, that the eyes of Vesalius° and of Harvey° might be dazzled by the sight of the tree that has grown out of their grain of mustard seed.

The fact is perhaps rather too much, than too little, forced upon one's notice, nowadays, that all this marvellous intellectual growth has a no

less wonderful expression in practical life; and that, in this respect, if in no other, the movement symbolized by the progress of the Royal Society stands without a parallel in the history of mankind.

A series of volumes as bulky as the "Transactions of the Royal Society" might possibly be filled with the subtle speculations of the Schoolmen°; not improbably, the obtaining a mastery over the products of mediæval thought might necessitate an even greater expenditure of time and of energy than the acquirement of the "New Philosophy"; but though such work engrossed the best intellects of Europe for a longer time than has elapsed since the great fire, its effects were "writ in water," so far as our social state is concerned.

On the other hand, if the noble first President of the Royal Society could revisit the upper air and once more gladden his eyes with a sight of the familiar mace, he would find himself in the midst of a material civilization more different from that of his day, than that of the seventeenth was from that of the first century. And if Lord Brouncker's native sagacity had not deserted his ghost, he would need no long reflection to discover

that all these great ships, these railways, these telegraphs, these factories, these printing-presses, without which the whole fabric of modern English society would collapse into a mass of stagnant and starving pauperism, — that all these pillars of our State are but the ripples and the bubbles upon the surface of that great spiritual stream, the springs of which only, he and his fellows were privileged to see; and seeing, to recognize as that which it behooved them above all things to keep pure and undefiled.

It may not be too great a flight of imagination to conceive our noble *revenant* not forgetful of the great troubles of his own day, and anxious to know how often London had been burned down since his time, and how often the plague had carried off its thousands. He would have to learn that, although London contains tenfold the inflammable matter that it did in 1666; though, not content with filling our rooms with woodwork and light draperies, we must needs lead inflammable and explosive gases into every corner of our streets and houses, we never allow even a street to burn down. And if he asked how this had come about,

we should have to explain that the improvement of natural knowledge has furnished us with dozens of machines for throwing water upon fires, any one of which would have furnished the ingenious Mr. Hooke,° the first "curator and experimenter" of the Royal Society, with ample materials for discourse before half a dozen meetings of that body; and that, to say truth, except for the progress of natural knowledge, we should not have been able to make even the tools by which these machines are constructed. And, further, it would be necessary to add, that although severe fires sometimes occur and inflict great damage, the loss is very generally compensated by societies, the operations of which have been rendered possible only by the progress of natural knowledge in the direction of mathematics, and the accumulation of wealth in virtue of other natural knowledge.

But the plague? My Lord Brouncker's observation would not, I fear, lead him to think that Englishmen of the nineteenth century are purer in life, or more fervent in religious faith, than the generation which could produce a Boyle,° an Evelyn,° and a Milton. He might find the mud of

society at the bottom, instead of at the top, but I fear that the sum total would be as deserving of swift judgment as at the time of the Restoration.° And it would be our duty to explain once more, and this time not without shame, that we have no reason to believe that it is the improvement of our faith, nor that of our morals, which keeps the plague from our city; but, again, that it is the improvement of our natural knowledge.

We have learned that pestilences will only take up their abode among those who have prepared unswept and ungarnished residences for them. Their cities must have narrow, unwatered streets, foul with accumulated garbage. Their houses must be ill-drained, ill-lighted, ill-ventilated. Their subjects must be ill-washed, ill-fed, ill-clothed. The London of 1665 was such a city. The cities of the East, where plague has an enduring dwelling, are such cities. We, in later times, have learned somewhat of Nature, and partly obey her. Because of this partial improvement of our natural knowledge and of that fractional obedience, we have no plague; because that knowledge is still very imperfect and that obedience yet incomplete, typhoid is

our companion and cholera our visitor. But it is not presumptuous to express the belief that, when our knowledge is more complete and our obedience the expression of our knowledge, London will count her centuries of freedom from typhoid and cholera, as she now gratefully reckons her two hundred years of ignorance of that plague which swooped upon her thrice in the first half of the seventeenth century.

Surely, there is nothing in these explanations which is not fully borne out by the facts? Surely, the principles involved in them are now admitted among the fixed beliefs of all thinking men? Surely, it is true that our countrymen are less subject to fire, famine, pestilence, and all the evils which result from a want of command over and due anticipation of the course of Nature, than were the countrymen of Milton; and health, wealth, and well-being are more abundant with us than with them? But no less certainly is the difference due to the improvement of our knowledge of Nature, and the extent to which that improved knowledge has been incorporated with the household words of men, and has supplied the springs of their daily actions.

Granting for a moment, then, the truth of that which the depreciators of natural knowledge are so fond of urging, that its improvement can only add to the resources of our material civilization; admitting it to be possible that the founders of the Royal Society themselves looked for no other reward than this, I cannot confess that I was guilty of exaggeration when I hinted, that to him who had the gift of distinguishing between prominent events and important events, the origin of a combined effort on the part of mankind to improve natural knowledge might have loomed larger than the Plague and have outshone the glare of the Fire; as a something fraught with a wealth of beneficence to mankind, in comparison with which the damage done by those ghastly evils would shrink into insignificance. It is very certain that for every victim slain by the plague, hundreds of mankind exist and find a fair share of happiness in the world by the aid of the spinning-jenny. And the great fire, at its worst, could not have burned the supply of coal, the daily working of which, in the bowels of the earth, made possible by the steam-pump, gives rise to an amount of wealth to which the

millions lost in old London are but as an old song.

But spinning-jenny and steam-pump are, after all, but toys, possessing an accidental value; and natural knowledge creates multitudes of more subtle contrivances, the praises of which do not happen to be sung because they are not directly convertible into instruments for creating wealth. When I contemplate natural knowledge squandering such gifts among men, the only appropriate comparison I can find for her is, to liken her to such a peasant woman as one sees in the Alps, striding ever upward, heavily burdened, and with mind bent only on her home; but yet without effort and without thought, knitting for her children. Now stockings are good and comfortable things, and the children will undoubtedly be much the better for them; but surely it would be short-sighted, to say the least of it, to depreciate this toiling mother as a mere stocking-machine — a mere provider of physical comforts?

However, there are blind leaders of the blind, and not a few of them, who take this view of natural

knowledge, and can see nothing in the bountiful mother of humanity but a sort of comfort-grinding machine. According to them, the improvement of natural knowledge always has been, and always must be, synonymous with no more than the improvement of the material resources and the increase of the gratifications of men.°

Natural knowledge is, in their eyes, no real mother of mankind, bringing them up with kindness, and, if need be, with sternness, in the way they should go, and instructing them in all things needful for their welfare; but a sort of fairy godmother, ready to furnish her pets with shoes of swiftness, swords of sharpness, and omnipotent Aladdin's° lamps, so that they may have telegraphs to Saturn, and see the other side of the moon, and thank God they are better than their benighted ancestors.

If this talk were true, I, for one, should not greatly care to toil in the service of natural knowledge. I think I would just as soon be quietly chipping my own flint axe, after the manner of my forefathers a few thousand years back, as be troubled with the endless malady of thought which now infests us all, for such reward. But I

venture to say that such views are contrary alike to reason and to fact. Those who discourse in such fashion seem to me to be so intent upon trying to see what is above Nature, or what is behind her, that they are blind to what stares them in the face in her.

I should not venture to speak thus strongly if my justification were not to be found in the simplest and most obvious facts, — if it needed more than appeal to the most notorious truths to justify my assertion, that the improvement of natural knowledge, whatever direction it has taken, and however low the aims of those who may have commenced it — has not only conferred practical benfits on men, but, in so doing, has effected a revolution in their conceptions of the universe and of themselves, and has profoundly altered their modes of thinking and their views of right and wrong. I say that natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings. I say that natural knowledge, in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundations of a new morality.

Let us take these points separately; and first, what great ideas has natural knowledge introduced into men's minds?

I cannot but think that the foundations of all natural knowledge were laid when the reason of man first came face to face with the facts of Nature; when the savage first learned that the fingers of one hand are fewer than those of both; that it is shorter to cross a stream than to head it; that a stone stops where it is unless it be moved, and that it drops from the hand which lets it go; that light and heat come and go with the sun; that sticks burn away in a fire; that plants and animals grow and die; that if he struck his fellow-savage a blow, he would make him angry, and perhaps get a blow in return, while if he offered him a fruit, he would please him, and perhaps receive a fish in exchange. When men had acquired this much knowledge, the outlines, rude though they were, of mathematics, of physics, of chemistry, of biology, of moral, economical, and political science, were sketched. Nor did the germ of religion fail when science began to bud. Listen to words which, though new, are yet three thousands years old:—

"... When in heaven the stars about the moon
Look beautiful, when all the winds are laid,
And every height comes out, and jutting peak
And valley, and the immeasurable heavens
Break open to their highest, and all the stars
Shine, and the shepherd gladdens in his heart." °

If the half-savage Greek could share our feelings thus far, it is irrational to doubt that he went further, to find, as we do, that upon that brief gladness there follows a certain sorrow, — the little light of awakened human intelligence shines so mere a spark amidst the abyss of the unknown and unknowable; seems so insufficient to do more than illuminate the imperfections that cannot be remedied, the aspirations that cannot be realized, of man's own nature. But in this sadness, this consciousness of the limitation of man, this sense of an open secret which he cannot penetrate, lies the essence of all religion; and the attempt to embody it in the forms furnished by the intellect is the origin of the higher theologies.

Thus it seems impossible to imagine but that the foundations of all knowledge — secular or sacred — were laid when intelligence dawned, though

the superstructure remained for long ages so slight and feeble as to be compatible with the existence of almost any general view respecting the mode of governance of the universe. No doubt, from the first, there were certain phenomena which, to the rudest mind, presented a constancy of occurrence, and suggested that a fixed order ruled, at any rate, among them. I doubt if the grossest of Fetish° worshippers ever imagined that a stone must have a god within it to make it fall, or that a fruit had a god within it to make it taste sweet. With regard to such matters as these, it is hardly questionable that mankind from the first took strictly positive and scientific views.

But, with respect to all the less familiar occurrences which present themselves, uncultured man, no doubt, has always taken himself as the standard of comparison, as the centre and measure of the world; nor could he well avoid doing so. And finding that his apparently uncaused will has a powerful effect in giving rise to many occurrences, he naturally enough ascribed other and greater events to other and greater volitions, and came to

look upon the world and all that therein is, as the product of the volitions of persons like himself, but stronger, and capable of being appeased or angered, as he himself might be soothed or irritated. Through such conceptions of the plan and working of the universe all mankind have passed, or are passing. And we may now consider what has been the effect of the improvement of natural knowledge on the views of men who have reached this stage, and who have begun to cultivate natural knowledge with no desire but that of "increasing God's honour and bettering man's estate."°

For example, what could seem wiser, from a mere material point of view, more innocent, from a theological one, to an ancient people, than that they should learn the exact succession of the seasons, as warnings for their husbandmen; or the position of the stars, as guides to their rude navigators? But what has grown out of this search for natural knowledge of so merely useful a character? You all know the reply. Astronomy, — which of all sciences has filled men's minds with general ideas of a character most foreign to their daily experience, and has, more than any other, rendered it impossible for them

to accept the beliefs of their fathers. Astronomy, — which tells them that this so vast and seemingly solid earth is but an atom among atoms, whirling, no man knows whither, through illimitable space; which demonstrates that what we call the peaceful heaven above us, is but that space, filled by an infinitely subtle matter whose particles are seething and surging, like the waves of an angry sea; which opens up to us infinite regions where nothing is known, or ever seems to have been known, but matter and force, operating according to rigid rules; which leads us to contemplate phenomena the very nature of which demonstrates that they must have had a beginning, and that they must have an end, but the very nature of which also proves that the beginning was, to our conceptions of time, infinitely remote, and that the end is as immeasurably distant.

But it is not alone those who pursue astronomy who ask for bread and receive ideas. What more harmless than the attempt to lift and distribute water by pumping it; what more absolutely and grossly utilitarian? Yet out of pumps grew the discussions about Nature's abhorrence of a vac-

uum; and then it was discovered that Nature does not abhor a vacuum, but that air has weight; and that notion paved the way for the doctrine that all matter has weight, and that the force which produces weight is co-extensive with the universe, — in short, to the theory of universal gravitation and endless force. While learning how to handle gases led to the discovery of oxygen,° and to modern chemistry, and to the notion of the indestructibility of matter.

Again, what simpler, or more absolutely practical, than the attempt to keep the axle of a wheel from heating when the wheel turns round very fast? How useful for carters and gig drivers to know something about this; and how good were it, if any ingenious person would find out the cause of such phenomena, and thence educe a general remedy for them. Such an ingenious person was Count Rumford°; and he and his successors have landed us in the theory of the persistence, or indestructibility, of force. And in the infinitely minute, as in the infinitely great, the seekers after natural knowledge of the kinds called physical and chemical, have everywhere found a definite order and succession of events which seem never to be infringed.

And how has it fared with "Physick" and Anatomy? Have the anatomist, the physiologist, or the physician, whose business it has been to devote themselves assiduously to that eminently practical and direct end, the alleviation of the sufferings of mankind, — have they been able to confine their vision more absolutely to the strictly useful? I fear they are the worst offenders of all. For if the astronomer has set before us the infinite magnitude of space, and the practical eternity of the duration of the universe; if the physical and chemical philosophers have demonstrated the infinite minuteness of its constituent parts, and the practical eternity of matter and of force; and if both have alike proclaimed the universality of a definite and predicable order and succession of events, the workers in biology have not only accepted all these, but have added more startling theses of their own. For, as the astronomers discover in the earth no centre of the universe, but an eccentric speck, so the naturalists find man to be no centre of the living world, but one amidst endless modifications of life°; and as the astronomer observes the mark of practically endless time set upon the arrangements of the solar

system, so the student of life finds the records of ancient forms of existence peopling the world for ages, which, in relation to human experience, are infinite.

Furthermore, the physiologist finds life to be as dependent for its manifestation on particular molecular arrangements as any physical or chemical phenomenon; and wherever he extends his researches, fixed order and unchanging causation reveal themselves, as plainly as in the rest of Nature.

Nor can I find that any other fate has awaited the germ of Religion. Arising, like all other kinds of knowledge, out of the action and interaction of man's mind, with that which is not man's mind, it has taken the intellectual coverings of Fetishism° or Polytheism°; of Theism° or Atheism°; of Superstition or Rationalism.° With these, and their relative merits and demerits, I have nothing to do; but this it is needful for my purpose to say, that if the religion of the present differs from that of the past, it is because the theology of the present has become more scientific than that of the past; because it has not only renounced idols of wood and idols of stone,

but begins to see the necessity of breaking in pieces the idols built up of books and traditions and fine-spun ecclesiastical cobwebs: and of cherishing the noblest and most human of man's emotions, by worship "for the most part of the silent sort" at the altar of the Unknown.°

Such are a few of the new conceptions implanted in our minds by the improvement of natural knowledge. Men have acquired the ideas of the practically infinite extent of the universe and of its practical eternity; they are familiar with the conception that our earth is but an infinitesimal fragment of that part of the universe which can be seen; and that, nevertheless, its duration is, as compared with our standards of time, infinite. They have further acquired the idea that man is but one of innumerable forms of life now existing on the globe, and that the present existences are but the last of an immeasurable series of predecessors. Moreover, every step they have made in natural knowledge has tended to extend and rivet in their minds the conception of a definite order of the universe — which is embodied in what are called, by an unhappy metaphor, the laws of Nature — and to narrow the

range and loosen the force of men's belief in spontaneity, or in changes other than such as arise out of that definite order itself.

Whether these ideas are well or ill founded is not the question. No one can deny that they exist, and have been the inevitable outgrowth of the improvement of natural knowledge. And if so, it cannot be doubted that they are changing the form of men's most cherished and most important convictions.

And as regards the second point — the extent to which the improvement of natural knowledge has remodelled and altered what may be termed the intellectual ethics of men, — what are among the moral convictions most fondly held by barbarous and semi-barbarous people.

They are the convictions that authority is the soundest basis of belief; that merit attaches to a readiness to believe; that the doubting disposition is a bad one, and scepticism a sin; that when good authority has pronounced what is to be believed, and faith has accepted it, reason has no further duty. There are many excellent persons who yet

hold by these principles, and it is not my present business, or intention, to discuss their views. All I wish to bring clearly before your minds is the unquestionable fact, that the improvement of natural knowledge is effected by methods which directly give the lie to all these convictions, and assume the exact reverse of each to be true.

The improver of natural knowledge absolutely refuses to acknowledge authority as such. For him, scepticism is the highest of duties; blind faith the one unpardonable sin. And it cannot be otherwise, for every great advance in natural knowledge has involved the absolute rejection of authority, the cherishing of the keenest scepticism, the annihilation of the spirit of blind faith; and the most ardent votary of science holds his firmest convictions, not because the men he most venerates hold them; not because their verity is testified by portents and wonders; but because his experience teaches him that whenever he chooses to bring these convictions into contact with their primary source, Nature — whenever he thinks fit to test them by appealing to experiment and to observation — Nature will confirm them. The

man of science has learned to believe in justification, not by faith, but by verification.[9]

Thus, without for a moment pretending to despise the practical results of the improvement of natural knowledge, and its beneficial influence on material civilization, it must, I think, be admitted that the great ideas, some of which I have indicated, and the ethical spirit which I have endeavoured to sketch, in the few moments which remained at my disposal, constitute the real and permanent significance of natural knowledge.

If these ideas be destined, as I believe they are, to be more and more firmly established as the world grows older; if that spirit be fated, as I believe it is, to extend itself into all departments of human thought, and to become co-extensive with the range of knowledge; if, as our race approaches its maturity, it discovers, as I believe it will, that there is but one kind of knowledge and but one method of acquiring it; then we, who are still children, may justly feel it our highest duty to recognize the advisableness of improving natural knowledge, and so to aid ourselves and our successors in our course towards the noble goal which lies before mankind.

III

A LIBERAL EDUCATION; AND WHERE TO FIND IT

The business which the South London Working Men's College has undertaken is a great work; indeed, I might say, that Education, with which that college proposes to grapple, is the greatest work of all those which lie ready to a man's hand just at present.

And, at length, this fact is becoming generally recognized. You cannot go anywhere without hearing a buzz of more or less confused and contradictory talk on this subject — nor can you fail to notice that, in one point at any rate, there is a very decided advance upon like discussions in former days. Nobody outside the agricultural interest now dares to say that education is a bad thing. If any representative of the once large

and powerful party, which, in former days, proclaimed this opinion, still exists in a semi-fossil state, he keeps his thoughts to himself. In fact, there is a chorus of voices, almost distressing in their harmony, raised in favour of the doctrine that education is the great panacea for human troubles, and that, if the country is not shortly to go to the dogs, everybody must be educated.

The politicians tell us, "you must educate the masses because they are going to be masters." The clergy join in the cry for education, for they affirm that the people are drifting away from church and chapel into the broadest infidelity. The manufacturers and the capitalists swell the chorus lustily. They declare that ignorance makes bad workmen; that England will be soon unable to turn out cotton goods, or steam-engines, cheaper than other people; and then, Ichabod!° Ichabod! the glory will be departed from us. And a few voices are lifted up in favour of the doctrine that the masses should be educated because they are men and women with unlimited capacities of being, doing, and suffering, and that it is as true now, as ever it was, that the people perish for lack of knowledge.

These members of the minority, with whom I confess I have a good deal of sympathy, are doubtful whether any of the other reasons urged in favour of the education of the people are of much value — whether, indeed, some of them are based upon either wise or noble grounds of action. They question if it be wise to tell people that you will do for them, out of fear of their power, what you have left undone, so long as your only motive was compassion for their weakness and their sorrows. And, if ignorance of everything which it is needful a ruler should know is likely to do so much harm in the governing classes of the future, why is it, they ask reasonably enough, that such ignorance in the governing classes of the past has not been viewed with equal horror?

Compare the average artisan and the average country squire, and it may be doubted if you will find a pin to choose between the two in point of ignorance, class feeling, or prejudice. It is true that the ignorance is of a different sort — that the class feeling is in favour of a different class, and that the prejudice has a distinct flavour of wrong-headedness in each case — but it is questionable if the one

is either a bit better, or a bit worse, than the other. The old protectionist theory is the doctrine of trades unions as applied by the squires, and the modern trades unionism is the doctrine of the squires applied by the artisans. Why should we be worse off under one *régime* than under the other?

Again, this sceptical minority asks the clergy to think whether it is really want of education which keeps the masses away from their ministrations — whether the most completely educated men are not as open to reproach on this score as the workmen; and whether, perchance, this may not indicate that it is not education which lies at the bottom of the matter?

Once more, these people, whom there is no pleasing, venture to doubt whether the glory, which rests upon being able to undersell all the rest of the world, is a very safe kind of glory — whether we may not purchase it too dear; especially if we allow education, which ought to be directed to the making of men, to be diverted into a process of manufacturing human tools, wonderfully adroit in the exercise of some technical industry, but good for nothing else.

And, finally, these people inquire whether it is the masses alone who need a reformed and improved education. They ask whether the richest of our public schools might not well be made to supply knowledge, as well as gentlemanly habits, a strong class feeling, and eminent proficiency in cricket. They seem to think that the noble foundations of our old universities are hardly fulfilling their functions in their present posture of half-clerical seminaries, half racecourses, where men are trained to win a senior wranglership,° or a double-first,° as horses are trained to win a cup, with as little reference to the needs of after-life in the case of the man as in that of the racer. And, while as zealous for education as the rest, they affirm that, if the education of the richer classes were such as to fit them to be the leaders and the governors of the poorer; and, if the education of the poorer classes were such as to enable them to appreciate really wise guidance and good governance; the politicians need not fear mob-law, nor the clergy lament their want of flocks, nor the capitalists prognosticate the annihilation of the prosperity of the country.

Such is the diversity of opinion upon the why and

the wherefore of education. And my hearers will be prepared to expect that the practical recommendations which are put forward are not less discordant. There is a loud cry for compulsory education. We English, in spite of constant experience to the contrary, preserve a touching faith in the efficacy of acts of parliament; and I believe we should have compulsory education in the course of next session, if there were the least probability that half a dozen leading statesmen of different parties would agree what that education should be.

Some hold that education without theology is worse than none. Others maintain, quite as strongly, that education with theology is in the same predicament. But this is certain, that those who hold the first opinion can by no means agree what theology should be taught, and that those who maintain the second are in a small minority.

At any rate "make people learn to read, write, and cipher," say a great many; and the advice is undoubtedly sensible as far as it goes. But, as has happened to me in former days, those who, in despair of getting anything better, advocate this measure, are met with the objection that it is very like

making a child practise the use of a knife, fork, and spoon without giving it a particle of meat. I really don't know what reply is to be made to such an objection.

But it would be unprofitable to spend more time in disentangling, or rather in showing up the knots in, the ravelled skeins of our neighbours. Much more to the purpose is it to ask if we possess any clew of our own which may guide us among these entanglements. And by way of a beginning, let us ask ourselves — What is education? Above all things, what is our ideal of a thoroughly liberal education? — of that education which, if we could begin life again, we would give ourselves — of that education which, if we could mould the fates to our own will, we would give our children. Well, I know not what may be your conceptions upon this matter, but I will tell you mine, and I hope I shall find that our views are not very discrepant.

Suppose it were perfectly certain that the life and fortune of every one of us would, one day or other, depend upon his winning or losing a game at chess. Don't you think that we should all consider it to be

a primary duty to learn at least the names and the moves of the pieces; to have a notion of a gambit° and a keen eye for all the means of giving and getting out of check°? Do you not think that we should look with a disapprobation amounting to scorn upon the father who allowed his son, or the state which allowed its members, to grow up without knowing a pawn from a knight°?

Yet it is a very plain and elementary truth, that the life, the fortune, and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. But also we know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well the

highest stakes are paid, with that sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated — without haste, but without remorse.

My metaphor will remind some of you of the famous picture in which Retzsch° has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, as we say, and would rather lose than win — and I should accept it as an image of human life.

Well, what I mean by Education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of Nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws.° For me, education means neither more nor less than this. Anything which professes to call itself education must be tried by this standard, and if it fails to stand the test, I will not call it education, whatever may be the force of authority, or of numbers, upon the other side.

It is important to remember that, in strictness, there is no such thing as an uneducated man. Take an extreme case. Suppose that an adult man, in the full vigour of his faculties, could be suddenly placed in the world, as Adam is said to have been, and then left to do as he best might. How long would he be left uneducated? Not five minutes. Nature would begin to teach him, through the eye, the ear, the touch, the properties of objects. Pain and pleasure would be at his elbow telling him to do this and avoid that; and by slow degrees the man would receive an education, which, if narrow, would be thorough, real, and adequate to his circumstances, though there would be no extras. and very few accomplishments.

And if to this solitary man entered a second Adam, or, better still, an Eve, a new and greater world, that of social and moral phenomena, would be revealed. Joys and woes, compared with which all others might seem but faint shadows, would spring from the new relations. Happiness and sorrow would take the place of the coarser monitors, pleasure and pain; but conduct would still be shaped by the observation of the natural consequences of

actions; or, in other words, by the laws or the nature of man.

To every one of us the world was once as fresh and new as to Adam. And then, long before we were susceptible of any other mode of instruction, Nature took us in hand, and every minute of waking life brought its educational influence, shaping our actions into rough accordance with Nature's laws, so that we might not be ended untimely by too gross disobedience. Nor should I speak of this process of education as past for any one, be he as old as he may. For every man the world is as fresh as it was at the first day, and as full of untold novelties for him who has the eyes to see them. And Nature is still continuing her patient education of us in that great university, the universe, of which we are all members — Nature having no Test-Acts.°

Those who take honours in Nature's university, who learn the laws which govern men and things and obey them, are the really great and successful men in this world. The great mass of mankind are the "Poll,"° who pick up just enough to get through without much discredit. Those who won't

learn at all are plucked; and then you can't come up again. Nature's pluck means extermination.

Thus the question of compulsory education is settled so far as Nature is concerned. Her bill on that question was framed and passed long ago. But, like all compulsory legislation, that of Nature is harsh and wasteful in its operation. Ignorance is visited as sharply as wilful disobedience — incapacity meets with the same punishment as crime. Nature's discipline is not even a word and a blow, and the blow first — but the blow without the word. It is left to you to find out why your ears are boxed.

The object of what we commonly call education — that education in which man intervenes and which I shall distinguish as artificial education — is to make good these defects in Nature's methods; to prepare the child to receive Nature's education, neither incapably nor ignorantly, nor with wilful disobedience; and to understand the preliminary symptoms of her displeasure, without waiting for the box on the ear. In short, all artificial education ought to be an anticipation of natural education. And a liberal education is an artificial education, which has not only prepared a man to escape

the great evils of disobedience to natural laws, but has trained him to appreciate and to seize upon the rewards which Nature scatters with as free a hand as her penalties.

That man, I think, has had a liberal education, who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of; whose intellect is a clear, cold, logic engine, with all its parts of equal strength, and in smooth working order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of Nature or of art, to hate all vileness, and to respect others as himself.

Such an one and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with Nature. He will make

the best of her, and she of him. They will get on together rarely; she as his ever beneficent mother; he as her mouth-piece, her conscious self, her minister and interpreter.

Where is such an education as this to be had? Where is there any approximation to it? Has any one tried to found such an education? Looking over the length and breadth of these islands, I am afraid that all these questions must receive a negative answer.° Consider our primary schools, and what is taught in them. A child learns: —

1. To read, write, and cipher, more or less well; but in a very large proportion of cases not so well as to take pleasure in reading, or to be able to write the commonest letter properly.

2. A quantity of dogmatic theology, of which the child, nine times out of ten, understands next to nothing.

3. Mixed up with this, so as to seem to stand or fall with it, a few of the broadest and simplest principles of morality. This, to my mind, is much as if a man of science should make the story of the fall of the apple in Newton's garden an integral

part of the doctrine of gravitation, and teach it as of equal authority with the law of the inverse squares.

4. A good deal of Jewish history and Syrian geography, and, perhaps, a little something about English history and the geography of the child's own country. But I doubt if there is a primary school in England in which hangs a map of the hundred° in which the village lies, so that the children may be practically taught by it what a map means.

5. A certain amount of regularity, attentive obedience, respect for others: obtained by fear, if the master be incompetent or foolish; by love and reverence, if he be wise.

So far as this school course embraces a training in the theory and practice of obedience to the moral laws of Nature, I gladly admit, not only that it contains a valuable educational element, but that, so far, it deals with the most valuable and important part of all education. Yet, contrast what is done in this direction with what might be done; with the time given to matters of comparatively no importance; with the absence of any attention to things of the highest moment; and one is tempted to think

of Falstaff's bill and "the halfpenny worth of bread to all that quantity of sack." °

Let us consider what a child thus "educated" knows, and what it does not know. Begin with the most important topic of all — morality, as the guide of conduct. The child knows well enough that some acts meet with approbation and some with disapprobation. But it has never heard that there lies in the nature of things a reason for every moral law, as cogent and as well defined as that which underlies every physical law; that stealing and lying are just as certain to be followed by evil consequences, as putting your hand in the fire, or jumping out of a garret window. Again, though the scholar may have been made acquainted, in dogmatic fashion, with the broad laws of morality, he has had no training in the application of those laws to the difficult problems which result from the complex conditions of modern civilization. Would it not be very hard to expect any one to solve a problem in conic sections who had merely been taught the axioms and definitions of mathematical science?

A workman has to bear hard labour, and perhaps

privation, while he sees others rolling in wealth, and feeding their dogs with what would keep his children from starvation. Would it not be well to have helped that man to calm the natural promptings of discontent by showing him, in his youth, the necessary connection of the moral law which prohibits stealing with the stability of society — by proving to him, once for all, that it is better for his own people, better for himself, better for future generations, that he should starve than steal? If you have no foundation of knowledge or habit of thought to work upon, what chance have you of persuading a hungry man that a capitalist is not a thief "with a circumbendibus" °? And if he honestly believes that, of what avail is it to quote the commandment against stealing, when he proposes to make the capitalist disgorge?

Again, the child learns absolutely nothing of the history or the political organization of his own country. His general impression is that everything of much importance happened a very long while ago; and that the Queen and the gentlefolks govern the country much after the fashion of King David and the elders and nobles of Israel — his

sole models. Will you give a man with this much information a vote? In easy times he sells it for a pot of beer. Why should he not? It is of about as much use to him as a chignon, and he knows as much what to do with it, for any other purpose. In bad times, on the contrary, he applies his simple theory of government, and believes that his rulers are the cause of his sufferings — a belief which sometimes bears remarkable practical fruits.

Least of all, does the child gather from this primary "education" of ours a conception of the laws of the physical world, or of the relations of cause and effect therein. And this is the more to be lamented, as the poor are especially exposed to physical evils, and are more interested in removing them than any other class of the community. If any one is concerned in knowing the ordinary laws of mechanics, one would think it is the hand-labourer, whose daily toil lies among levers and pulleys, or among the other implements of artisan work. And if any one is interested in the laws of health, it is the poor workman, whose strength is wasted by ill-prepared food, whose health is sapped by bad ventilation and bad drainage, and half whose chil-

dren are massacred by disorders which might be prevented. Not only does our present primary education carefully abstain from hinting to the workman that some of his greatest evils are traceable to mere physical agencies, which could be removed by energy, patience, and frugality; but it does worse — it renders him, so far as it can, deaf to those who could help him, and tries to substitute an Oriental submission to what is falsely declared to be the will of God, for his natural tendency to strive after a better condition.

What wonder then, if very recently an appeal has been made to statistics for the profoundly foolish purpose of showing that education is of no good — that it diminishes neither misery, nor crime, among the masses of mankind? I reply, why should the thing which has been called education do either the one or the other? If I am a knave or a fool, teaching me to read and write won't make me less of either one or the other — unless somebody shows me how to put my reading and writing to wise and good purposes.

Suppose any one were to argue that medicine is of no use, because it could be proved statistically that

the percentage of deaths was just the same, among people who had been taught how to open a medicine chest, and among those who did not so much as know the key by sight. The argument is absurd; but it is not more preposterous than that against which I am contending. The only medicine for suffering, crime, and all the other woes of mankind, is wisdom. Teach a man to read and write, and you have put into his hands the great keys of the wisdom box. But it is quite another matter whether he ever opens the box or not. And he is as likely to poison as to cure himself, if, without guidance, he swallows the first drug that comes to hand. In these times a man may as well be purblind, as unable to read — lame, as unable to write. But I protest that, if I thought the alternative were a necessary one, I would rather that the children of the poor should grow up ignorant of both these mighty arts, than that they should remain ignorant of that knowledge to which these arts are means.

It may be said that all these animadversions may apply to primary schools, but that the higher schools, at any rate, must be allowed to give a liberal edu-

cation. In fact, they professedly sacrifice everything else to this object.

Let us inquire into this matter. What do the higher schools, those to which the great middle class of the country sends it children, teach, over and above the instruction given in the primary schools? There is a little more reading and writing of English. But, for all that, every one knows that it is a rare thing to find a boy of the middle or upper classes who can read aloud decently, or who can put his thoughts on paper in clear and grammatical (to say nothing of good or elegant) language. The "ciphering" of the lower schools expands into elementary mathematics in the higher; into arithmetic, with a little algebra, a little Euclid.° But I doubt if one boy in five hundred has ever heard the explanation of a rule of arithmetic, or knows his Euclid otherwise than by rote.

Of theology, the middle-class schoolboy gets rather less than poorer children, less absolutely and less relatively, because there are so many other claims upon his attention. I venture to say that, in the great majority of cases, his ideas on this subject when he leaves school are of the most shad-

owy and vague description, and associated with painful impressions of the weary hours spent in learning collects and catechism by heart.

Modern geography, modern history,° modern literature; the English language as a language; the whole circle of the sciences, physical, moral, and social, are even more completely ignored in the higher than in the lower schools. Up till within a few years back, a boy might have passed through any one of the great public schools° with the greatest distinction and credit, and might never so much as have heard of one of the subjects I have just mentioned. He might never have heard that the earth goes round the sun; that England underwent a great revolution in 1688°; and France another in 1789°; that there once lived certain notable men called Chaucer,° Shakspeare,° Milton,° Voltaire,° Goethe,° Schiller.° The first might be a German and the last an Englishman for anything he could tell you to the contrary. And as for science, the only idea the word would suggest to his mind would be dexterity in boxing.

I have said that this was the state of things a few years back, for the sake of the few righteous who are

to be found among the educational cities of the plain. But I would not have you too sanguine about the result, if you sound the minds of the existing generation of public schoolboys, on such topics as those I have mentioned.

Now let us pause to consider this wonderful state of affairs; for the time will come when Englishmen will quote it as the stock example of the stolid stupidity of their ancestors in the nineteenth century. The most thoroughly commercial people, the greatest voluntary wanderers and colonists the world has ever seen, are precisely the middle classes of this country. If there be a people which has been busy making history on the great scale for the last three hundred years, — and the most profoundly interesting history — history which, if it happened to be that of Greece or Rome, we should study with avidity, — it is the English. If there be a people which, during the same period, has developed a remarkable literature, it is our own. If there be a nation whose prosperity depends absolutely and wholly upon their mastery over the forces of Nature, upon their intelligent apprehension of, and obedience to, the laws of the creation and distribution of wealth, and

of the stable equilibrium of the forces of society, it is precisely this nation. And yet this is what these wonderful people tell their sons: "At the cost of from one to two thousand pounds of our hard-earned money, we devote twelve of the most precious years of your lives to school. There you shall toil, or be supposed to toil; but there you shall not learn one single thing of all those you will most want to know, directly you leave school and enter upon the practical business of life. You will in all probability go into business, but you shall not know where or how any article of commerce is produced, or the difference between an export or an import, or the meaning of the word 'capital.' You will very likely settle in a colony, but you shall not know whether Tasmania is part of New South Wales, or *vice versa*.

"Very probably you may become a manufacturer, but you shall not be provided with the means of understanding the working of one of your own steam-engines, or the nature of the raw products you employ; and when you are asked to buy a patent, you shall not have the slightest means of judging whether the inventor is an impostor who is

contravening the elementary principles of science, or a man who will make you as rich as Crœsus.°

"You will very likely get into the House of Commons. You will have to take your share in making laws which may prove a blessing or a curse to millions of men. But you shall not hear one word respecting the political organization of your country; the meaning of the controversy between free-traders and protectionists shall never have been mentioned to you; you shall not so much as know that there are such things as economical laws.

"The mental power which will be of most importance in your daily life will be the power of seeing things as they are without regard to authority, and of drawing accurate general conclusions from particular facts. But at school and at college you shall know of no source of truth but authority; nor exercise your reasoning faculty upon anything but deduction from that which is laid down by authority.

"You will have to weary your soul with work, and many a time eat your bread in sorrow and in bitterness, and you shall not have learned to take refuge in the great source of pleasure without alloy,

the serene resting-place for worn human nature, — the world of art."

Said I not rightly that we are a wonderful people? I am quite prepared to allow, that education entirely devoted to these omitted subjects might not be a completely liberal education. But is an education which ignores them all a liberal education? Nay, is it too much to say that the education which should embrace these subjects and no others, would be a real education, though an incomplete one; while an education which omits them is really not an education at all, but a more or less useful course of intellectual gymnastics?

For what does the middle-class school put in the place of all these things which are left out? It substitutes what is usually comprised under the compendious title of the "classics" — that is to say, the languages, the literature, and the history of the ancient Greeks and Romans, and the geography of so much of the world as was known to these two great nations of antiquity. Now, do not expect me to depreciate the earnest and enlightened pursuit of classical learning. I have not the least desire

to speak ill of such occupations, nor any sympathy with those who run them down. On the contrary, if my opportunities had lain in that direction, there is no investigation into which I could have thrown myself with greater delight than that of antiquity.

What science can present greater attractions than philology? How can a lover of literary excellence fail to rejoice in the ancient masterpieces? And with what consistency could I, whose business lies so much in the attempt to decipher the past, and to build up intelligible forms out of the scattered fragments of long-extinct beings, fail to take a sympathetic, though an unlearned, interest in the labours of a Niebuhr,° a Gibbon,° or a Grote°? Classical history is a great section of the palæontology of man; and I have the same double respect for it as for other kinds of palæontology — that is to say, a respect for the facts which it establishes as for all facts, and a still greater respect for it as a preparation for the discovery of a law of progress.

But if the classics were taught as they might be taught — if boys and girls were instructed in Greek and Latin, not merely as languages, but as illustrations of philological science; if a vivid picture of

life on the shores of the Mediterranean, two thousand years ago, were imprinted on the minds of scholars; if ancient history were taught, not as a weary series of feuds and fights, but traced to its causes in such men placed under such conditions; if, lastly, the study of the classical books were followed in such a manner as to impress boys with their beauties, and with the grand simplicity of their statement of the everlasting problems of human life, instead of with their verbal and grammatical peculiarities; I still think it as little proper that they should form the basis of a liberal education for our contemporaries, as I should think it fitting to make that sort of palæontology with which I am familiar, the backbone of modern education.

It is wonderful how close a parallel to classical training could be made out of that palæontology to which I refer. In the first place I could get up an osteological primer so arid, so pedantic in its terminology,° so altogether distasteful to the youthful mind, as to beat the recent famous production of the head-masters out of the field in all these excellences. Next, I could exercise my boys upon easy fossils, and bring out all their powers of memory

and all their ingenuity in the application of my osteo-grammatical rules to the interpretation, or construing, of those fragments. To those who had reached the higher classes, I might supply odd bones to be built up into animals, giving great honour and reward to him who succeeded in fabricating monsters most entirely in accordance with the rules. That would answer to verse-making and essay-writing in the dead languages.

To be sure, if a great comparative anatomist were to look at these fabrications he might shake his head or laugh. But what then? Would such a catastrophe destroy the parallel? What think you would Cicero° or Horace° say to the production of the best sixth form° going? And would not Terence° stop his ears and run out if he could be present at an English performance of his own plays? Would Hamlet, in the mouths of a set of French actors, who should insist on pronouncing English after the fashion of their own tongue, be more hideously ridiculous?

But it will be said that I am forgetting the beauty, and the human interest which appertain to classical studies. To this I reply that it is only a very

strong man who can appreciate the charms of a landscape as he is toiling up a steep hill along a bad road. What with short-windedness, stones, ruts, and a pervading sense of the wisdom of rest and be thankful, most of us have little enough sense of the beautiful under these circumstances. The ordinary schoolboy is precisely in this case. He finds Parnassus° uncommonly steep, and there is no chance of his having much time or inclination to look about him till he gets to the top. And nine times out of ten he does not get to the top.

But if this be a fair picture of the results of classical teaching at its best, — and I gather from those who have authority to speak on such matters that it is so, — what is to be said of classical teaching at its worst, or in other words, of the classics of our ordinary middle-class schools°? I will tell you. It means getting up endless forms and rules by heart. It means turning Latin and Greek into English, for the mere sake of being able to do it, and without the smallest regard to the worth, or worthlessness, of the author read. It means the learning of innumerable, not always decent, fables in such a shape that the meaning they once had is

dried up into utter trash; and the only impression left upon a boy's mind is, that the people who believed such things must have been the greatest idiots the world ever saw. And it means, finally, that after a dozen years spent at this kind of work, the sufferer shall be incompetent to interpret a passage in an author he has not already got up; that he shall loathe the sight of a Greek or Latin book; and that he shall never open or think of a classical writer again, until, wonderful to relate, he insists upon submitting his sons to the same process.

These be your gods, O Israel°! For the sake of this net result (and respectability) the British father denies his children all the knowledge they might turn to account in life, not merely for the achievement of vulgar success, but for guidance in the great crises of human existence. This is the stone he offers to those whom he is bound by the strongest and tenderest ties to feed with bread.

If primary and secondary education are in this unsatisfactory state, what is to be said to the universities? This is an awful subject, and one I almost fear to touch with my unhallowed hands;

but I can tell you what those say who have authority to speak.

The Rector of Lincoln College,° in his lately published valuable "Suggestions for Academical Organization with Especial Reference to Oxford," tells us (p. 127): —

"The colleges were, in their origin, endowments, not for the elements of a general liberal education, but for the prolonged study of special and professional faculties by men of riper age. The universities embraced both these objects. The colleges, while they incidentally aided in elementary education, were specially devoted to the highest learning. . . .

"This was the theory of the middle-age university and the design of collegiate foundations in their origin. Time and circumstances have brought about a total change. The colleges no longer promote the researches of science or direct professional study. Here and there college walls may shelter an occasional student, but not in larger proportions than may be found in private life. Elementary teaching of youths under twenty is now the only function performed by the university, and almost the only

object of college endowments. Colleges were homes for the life-study of the highest and most abstruse parts of knowledge. They have become boarding schools in which the elements of the learned languages are taught to youths."

If Mr. Pattison's high position and his obvious love and respect for his university be insufficient to convince the outside world that language so severe is yet no more than just, the authority of the Commissioners who reported on the University of Oxford in 1850 is open to no challenge. Yet they write: —

"It is generally acknowledged that both Oxford and the country at large suffer greatly from the absence of a body of learned men devoting their lives to the cultivation of science and to the direction of academical education.

"The fact that so few books of profound research emanate from the University of Oxford, materially impairs its character as a seat of learning, and consequently its hold on the respect of the nation."

Cambridge can claim no exemption from the reproaches addressed to Oxford. And thus there seems no escape from the admission that what we

fondly call our great seats of learning are simply "boarding schools" for bigger boys; that learned men are not more numerous in them than out of them; that the advancement of knowledge is not the object of fellows of colleges; that, in the philosophic calm and meditative stillness of their greenswarded courts, philosophy does not thrive, and meditation bears few fruits.

It is my great good fortune to reckon amongst my friends resident members of both universities, who are men of learning and research, zealous cultivators of science, keeping before their minds a noble ideal of a university, and doing their best to make that ideal a reality; and, to me, they would necessarily typify the universities, did not the authoritative statements I have quoted compel me to believe that they are exceptional, and not representative men. Indeed, upon calm consideration, several circumstances lead me to think that the Rector of Lincoln College and the Commissioners cannot be far wrong.

I believe there can be no doubt that the foreigner who should wish to become acquainted with the scientific or the literary activity of modern Eng-

land would simply lose his time and his pains if he visited our universities with that object.

And as for works of profound research on any subject and, above all, in that classical lore for which the universities profess to sacrifice almost everything else, why, a third-rate, poverty-stricken German university turns out more produce of that kind in one year than our vast and wealthy foundations elaborate in ten.

Ask the man who is investigating any question, profoundly and thoroughly, — be it historical, philosophical, philological, physical, literary, or theological; who is trying to make himself master of any abstract subject (except, perhaps, political economy and geology, both of which are intensely Anglican sciences), — whether he is not compelled to read half a dozen times as many German as English books? And whether, of these English books, more than one in ten is the work of a fellow of a college or a professor of an English university?

Is this from any lack of power in the English as compared with the German mind? The countrymen of Grote and of Mill,° of Faraday,° of Robert Brown,° of Lyell,° and of Darwin,° to go no further

back than the contemporaries of men of middle age, can afford to smile at such a suggestion. England can show now, as she has been able to show in every generation since civilization spread over the West, individual men who hold their own against the world, and keep alive the old tradition of her intellectual eminence.

But in the majority of cases these men are what they are in virtue of their native intellectual force, and of a strength of character which will not recognize impediments. They are not trained in the courts of the Temple of Science, but storm the walls of that edifice in all sorts of irregular ways, and with much loss of time and power, in order to obtain their legitimate positions.

Our universities not only do not encourage such men; do not offer them positions, in which it should be their highest duty to do, thoroughly, that which they are most capable of doing; but, as far as possible, university training shuts out of the minds of those among them, who are subjected to it, the prospect that there is anything in the world for which they are specially fitted. Imagine the success of the attempt to still the intellectual hunger

of any of the men I have mentioned, by putting before him, as the object of existence, the successful mimicry of the measure of a Greek song, or the roll of Ciceronian prose! Imagine how much success would be likely to attend the attempt to persuade such men, that the education which leads to perfection in such elegancies is alone to be called culture; while the facts of history, the process of thought, the conditions of moral and social existence, and the laws of physical nature, are left to be dealt with as they may by outside barbarians!

It is not thus that the German universities, from being beneath notice a century ago, have become what they are now — the most intensely cultivated and the most productive intellectual corporations the world has ever seen.

The student who repairs to them sees in the list of classes and of professors a fair picture of the world of knowledge. Whatever he needs to know there is some one ready to teach him, some one competent to discipline him in the way of learning; whatever his special bent, let him but be able and diligent, and in due time he shall find distinction and a career. Among his professors, he sees men

whose names are known and revered throughout the civilized world; and their living example infects him with a noble ambition and a love for the spirit of work.

The Germans dominate the intellectual world by virtue of the same simple secret as that which made Napoleon the master of old Europe. They have declared *la carrière ouverte aux talents,*° and every Bursch° marches with a professor's gown in his knapsack. Let him become a great scholar or man of science, and ministers will compete for his services. In Germany they do not leave the chance of his holding the office he would render illustrious to the tender mercies of a hot canvass, and the final wisdom of a mob of country parsons.

In short, in Germany the universities are exactly what the Rector of Lincoln and the Commissioners tell us the English universities are not; that is to say, corporations "of learned men devoting their lives to the cultivation of science and the direction of academical education." They are not "boarding schools for youths" nor clerical seminaries, but institutions for the higher culture of men, in which the theological faculty is of no more impor-

tance or prominence than the rest; and which are truly "universities," since they strive to represent and embody the totality of human knowledge, and to find room for all forms of intellectual activity.

May zealous and clear-headed reformers like Mr. Pattison succeed in their noble endeavours to shape our universities towards some such ideals as this, without losing what is valuable and distinctive in their social tone! But until they have succeeded, a liberal education will be no more obtainable in our Oxford and Cambridge Universities than in our public schools.°

If I am justified in my conception of the ideal of a liberal education; and if what I have said about the existing educational institutions of the country is also true, it is clear that the two have no sort of relation to one another; that the best of our schools and the most complete of our university trainings give but a narrow, one-sided, and essentially illiberal education — while the worst give what is really next to no education at all. The South London Working-Men's College could not copy any of these institutions if it would. I am bold enough

to express the conviction that it ought not if it could.

For what is wanted is the reality and not the mere name of a liberal education; and this College must steadily set before itself the ambition to be able to give that education sooner or later. At present we are but beginning, sharpening our educational tools, as it were, and, except a modicum of physical science, we are not able to offer much more than is to be found in an ordinary school.

Moral and social science — one of the greatest and most fruitful of our future classes, I hope — at present lacks only one thing in our programme, and that is a teacher. A considerable want, no doubt; but it must be recollected that it is much better to want a teacher than to want the desire to learn.

Further, we need what, for want of a better name, I must call Physical Geography. What I mean is that which the Germans call "*Erdkunde.*" It is a description of the earth, of its place and relation to other bodies; of its general structure, and of its great features — winds, tides, mountains, plains; of the chief forms of the vegetable and

animal worlds, of the varieties of man. It is the peg upon which the greatest quantity of useful and entertaining scientific information can be suspended.

Literature is not upon the College programme, but I hope some day to see it there. For literature is the greatest of all sources of refined pleasure, and one of the great uses of a liberal education is to enable us to enjoy that pleasure. There is scope enough for the purposes of a liberal education in the study of the rich treasures of our own language alone.° All that is needed is direction, and the cultivation of a refined taste by attention to sound criticism. But there is no reason why French and German should not be mastered sufficiently to read what is worth reading in those languages with pleasure and with profit.

And finally, by and by, we must have History; treated not as a succession of battles and dynasties; not as a series of biographies; not as evidence that Providence has always been on the side of either Whigs or Tories; but as the development of man in times past, and in other conditions than our own.

But, as it is one of the principles of our College to be self-supporting, the public must lead, and we

must follow, in these matters. If my hearers take to heart what I have said about liberal education, they will desire these things, and I doubt not we shall be able to supply them. But we must wait till the demand is made.

IV

ON A PIECE OF CHALK

A LECTURE TO WORKING MEN

If a well were to be sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as "chalk."

Not only here, but over the whole county of Norfolk, the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and on the sea-coast, where the waves have pared away the face of the land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward the chalk may be followed as far as Yorkshire; on the south coast it appears abruptly in the picturesque western bays of Dorset, and breaks into the Needles

of the Isle of Wight; while on the shores of Kent it supplies that long line of white cliffs to which England owes her name of Albion.

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader and there narrower, might be followed diagonally across England from Lulworth in Dorset to Flamborough Head in Yorkshire — a distance of over 280 miles as the crow flies.

From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent and Sussex, it enters into the very foundation of all the southeastern counties.

Attaining, as it does in some places, a thickness of more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, which has precisely the same general characters as ours, and is found in detached patches, some less and others more extensive than the English.

Chalk occurs in northwest Ireland; it stretches

over a large part of France, — the chalk which underlies Paris being, in fact, a continuation of that of the London basin; it runs through Denmark and Central Europe, and extends southward to North Africa; while eastward, it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia.

If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3000 miles in long diameter; the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea — the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs and rounded coombs, covered with sweet-grassed turf, of our inland chalk country have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out

in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And, in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

What is this widespread component of the surface of the earth? and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification.

If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history

of man can be supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of the history of the globe, which I hope to enable you to read with your own eyes to-night.

Let me add that few chapters of human history have a more profound significance for ourselves. I weigh my words well when I assert that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature.

The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we "burn" chalk the result is quicklime. Chalk, in fact, is a compound of

carbonic acid gas and lime, and when you make it very hot the carbonic acid flies away, and the lime is left.

By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in the bubbles; the lime, dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of "carbonate of lime."

It is desirable for us to start from the knowledge of this fact, though it may not seem to help us very far towards what we seek. For carbonate of lime is a widely spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which

have drained through limestone rocks, in the form of what are called stalagmites and stalactites, is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a tea-kettle is carbonate of lime; and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it — until it is thin enough, in fact, to be examined with any magnifying power that may be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But the slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but embedded in this matrix, are innumerable bodies, some smaller and some larger,

but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure. A cubic inch of some specimens of chalk may contain hundreds of thousands of these bodies, compacted together with incalculable millions of the granules.

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are arranged, and of their relative proportions. But by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly grown raspberry, being formed of a number of nearly globular chambers of different

sizes congregated together. It is called *Globigerina*, and some specimens of chalk consist of little else than *Globigerinæ* and granules.

Let us fix our attention upon the *Globigerina*. It is the spoor of the game we are tracking. If we can learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is, that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage, — proving that the mere mineral water may, under certain conditions, assume the outward form of organic bodies, — so this mineral substance, carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature; and if no such conception is at present held to be admissible, it is because long and

varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If any one were to try to persuade you that an oyster-shell (which is also chiefly composed of carbonate of lime) had crystallized out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster-shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that *Globigerina* is not the product of anything but vital activity.

Happily, however, better evidence in proof of the organic nature of the *Globigerinæ* than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the *Globigerinæ* of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of the sea-shore, over a large extent of that part of the earth's surface which is covered by the ocean.

The history of the discovery of these living *Globigerinæ*, and of the part which they play in rock

building, is singular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very different and exceedingly practical interests.

When men first took to the sea, they speedily learned to look out for shoals and rocks; and the more the burthen of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding line; and, ultimately, marine surveying, which is the recording of the form of coasts and of the depth of the sea, as ascertained by the sounding-lead, upon charts.

At the same time, it became desirable to ascertain and to indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by "arming" the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well

adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieutenant Brooke, of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up from any depth to which the lead descends.

In 1853 Lieutenant Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland and the Azores, at a depth of more than 10,000 feet, or two miles, by the help of this sounding apparatus. The specimens were sent for examination to Ehrenberg° of Berlin and to Bailey of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms — the greater proportion of these being just like the *Globigerinæ* already known to occur in the chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieutenant Brooke's method of sounding acquired a high commercial

value, when the enterprise of laying down the telegraph cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly rope. The Admiralty consequently ordered Captain Dayman, an old friend and shipmate of mine,° to ascertain the depth over the whole line of the cable and to bring back specimens of the bottom. In former days such a command as this might have sounded very much like one of the impossible things which the young prince in the fairy tales is ordered to do before he can obtain the hand of the princess. However, in the months of June and July, 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud which he procured were sent to me to be examined and reported upon.

The result of all these operations is, that we know the contours and the nature of the surface soil

covered by the North Atlantic for a distance of 1700 miles from east to west, as well as we know that of any part of the dry land.

It is a prodigious plain — one of the widest and most even plains in the world. If the sea were drained off, you might drive a wagon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And, except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie down-hill for about 200 miles to the point at which the bottom is now covered by 1700 fathoms of sea-water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 feet; and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences and gradually leads, for about 300 miles, to the Newfoundland shore.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a grayish white friable substance. You can write with this on a blackboard, if you are so inclined; and, to the eye, it is quite like very soft, grayish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable *Globigerinæ* embedded in a granular matrix.

Thus this deep-sea mud is substantially chalk. I say substantially, because there are a good many minor differences; but as these have no bearing on the question immediately before us, — which is the nature of the *Globigerinæ* of the chalk, — it is unnecessary to speak of them.

Globigerinæ of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the *Globigerina* shell, or

rather skeleton, owes its existence — and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind — without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface long filamentous processes, which serve for arms and legs. Yet this amorphous particle, devoid of everything which, in the higher animals, we call organs, is capable of feeding, growing, and multiplying; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living *Globigerinæ* have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life; and it is not so absolutely impossible, as it might at first sight appear to be, that the *Globigerinæ* of the Atlantic sea-bottom do not live and die where they are found.

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of *Globigerinæ*, with the granules which have been mentioned, and some few other calcareous shells; but a small percentage of the chalky mud — perhaps at most some five per cent of it — is of a different nature, and consists of shells and skeletons composed of silex, or pure flint. These silicious bodies belong partly to the lowly vegetable organisms which are called *Diatomaceæ*, and partly to the minute and extremely simple animals termed *Radiolaria*. It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface — where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these silicious organisms, though they are not heavier than the lightest dust, must have fallen, in some cases, through fifteen thousand feet of water, before they reached their final resting-place on the ocean floor. And, considering how large a surface these bodies expose in proportion to their weight, it is probable that they occupy a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

But if the *Radiolaria* and Diatoms are thus rained upon the bottom of the sea, from the superficial layer of its waters in which they pass their lives, it is obviously possible that the *Globigerinæ* may be similarly derived; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea *Globigerinæ* are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating; and, as a matter of fact, they are not to be found along with the Diatoms and *Radiolaria* in the uppermost stratum of the open ocean.

It has been observed, again, that the abundance of *Globigerinæ*, in proportion to other organisms of like kind, increases with the depth of the sea, and that deep-water *Globigerinæ* are larger than those which live in shallower parts of the sea; and such facts negative the supposition that these organisms have been swept by currents from the shallows into the deeps of the Atlantic.

It therefore seems to be hardly doubtful that these

wonderful creatures live and die at the depths in which they are found.

However, the important points for us are that the living *Globigerinæ* are exclusively marine animals, the skeletons of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the *Globigerinæ* of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

In working over the soundings collected by Captain Dayman, I was surprised to find that many of what I have called the "granules" of that mud, were not, as one might have been tempted to think at first, the mere powder and waste of *Globigerinæ*, but that they had a definite form and size. I termed these bodies "*coccoliths*," and doubted their organic nature. Dr. Wallich verified my observation, and added the interesting discovery that, not unfrequently, bodies similar to these "coccoliths," were aggregated together into spheroids, which he termed "*coccospheres*." So far as we knew, these bodies, the nature of which is extremely puzzling

and problematical, were peculiar to the Atlantic soundings.

But a few years ago Mr. Sorby, in making a careful examination of the chalk by means of thin sections and otherwise, observed, as Ehrenberg had done before him, that much of its granular basis possesses a definite form. Comparing these formed particles with those in the Atlantic soundings, he found the two to be identical; and thus proved that the chalk, like the soundings, contains these mysterious coccoliths and coccospheres. Here was a further and a most interesting confirmation, from internal evidence, of the essential identity of the chalk with modern deep-sea mud. *Globigerinæ*, coccoliths, and coccospheres are found as the chief constituents of both, and testify to the general similarity of the conditions under which both have been formed.

The evidence furnished by the hewing, facing, and superposition of the stones of the Pyramids, that these structures were built by men, has no greater weight than the evidence that the chalk was built by *Globigerinæ;* and the belief that those ancient pyramid-builders were terrestrial and air-

breathing creatures like ourselves,—is it not better based than the conviction that the chalk-makers lived in the sea?

But as our belief in the building of the Pyramids by men is not only grounded on the internal evidence afforded by these structures, but gathers strength from multitudinous collateral proofs, and is clinched by the total absence of any reason for a contrary belief; so the evidence drawn from the *Globigerinæ* that the chalk is an ancient sea-bottom is fortified by innumerable independent lines of evidence; and our belief in the truth of the conclusion to which all positive testimony tends receives the like negative justification from the fact that no other hypothesis has a shadow of foundation.

It may be worth while briefly to consider a few of these collateral proofs that the chalk was deposited at the bottom of the sea.

The great mass of the chalk is composed, as we have seen, of the skeletons of *Globigerinæ*, and other simple organisms, embedded in granular matter. Here and there, however, this hardened mud of the ancient sea reveals the remains of higher animals which have lived and died, and left their

hard parts in the mud, just as the oysters die and leave their shells behind them in the mud of the present seas.

There are, at the present day, certain groups of animals which are never found in fresh waters, being unable to live anywhere but in the sea. Such are the corals; those corallines which are called *Polyzoa;* those creatures which fabricate the lamp-shells, and are called *Brachiopoda;* the pearly *Nautilus*, and all animals allied to it; and all the forms of sea-urchins and star-fishes.

Not only are all these creatures confined to salt water at the present day, but, so far as our records of the past go, the conditions of their existence have been the same; hence their occurrence in any deposit is as strong evidence as can be obtained, that that deposit was formed in the sea. Now the remains of animals of all the kinds which have been enumerated occur in the chalk in greater or less abundance, while not one of those forms of shell-fish which are characteristic of fresh water has yet been observed in it.

When we consider that the remains of more than three thousand distinct species of aquatic animals

have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water — the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land at present occupied by the chalk was once at the bottom of the sea, as we have for any matter of history whatever; while there is no justification for any other belief.

No less certain it is that the time during which the countries we now call southeast England, France, Germany, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration.

We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me that it must have taken some time for the skeletons of animalcules of a hundredth of an inch in diameter to heap up such a mass as that.

I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shell-fishes are commonly adherent; the long spines of some of the sea-urchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as much of the chalk as had then been deposited; and that each has been covered up by the layer of *Globigerina* mud upon which the creatures embedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

There is more curious evidence, again, that the process of covering up, or, in other words, the deposit of *Globigerina* skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose

all its outward coverings and appendages by putrefaction, and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

Cases of this kind are admirably described by Sir Charles Lyell.° He speaks of the frequency with which geologists find in the chalk a fossilized sea-urchin to which is attached the lower valve of a *Crania*. This is a kind of shell-fish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

"The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white chalk at some distance. In this case, we see clearly that the sea-urchin first lived from youth to age, then died and lost its spines, which were carried away. Then the young *Crania* adhered to the bared shell, grew and perished in its turn; after which, the upper valve was separated from the lower, before the Echinus° became enveloped in chalky mud." °

A specimen in the Museum of Practical Geology, in London, still further prolongs the period which

must have elapsed between the death of the sea-urchin and its burial by the *Globigerinæ*. For the outward face of the valve of a *Crania*, which is attached to a sea-urchin (*Micraster*), is itself overrun by an incrusting coralline, which spreads thence over more or less of the surface of the sea-urchin. It follows that, after the upper valve of the *Crania* fell off, the surface of the attached valve must have remained exposed long enough to allow of the growth of the whole coralline, since corallines do not live embedded in mud.

The progress of knowledge may, one day, enable us to deduce from such facts as these the maximum rate at which the chalk can have accumulated, and thus to arrive at the minimum duration of the chalk period. Suppose that the valve of the *Crania* upon which a coralline has fixed itself in the way just described, is so attached to the sea-urchin that no part of it is more than an inch above the face upon which the sea-urchin rests. Then, as the coralline could not have fixed itself, if the *Crania* had been covered up with chalk mud, and could not have lived had itself been so covered, it follows that an inch of chalk mud could not have accumulated

within the time between the death and decay of the soft parts of the sea-urchin and the growth of the coralline to the full size which it has attained. If the decay of the soft parts of the sea-urchin, the attachment, growth to maturity, and decay of the *Crania*, and the subsequent attachment and growth of the coralline, took a year (which is a low estimate enough), the accumulation of the inch of chalk must have taken more than a year; and the deposit of a thousand feet of chalk must, consequently, have taken more than twelve thousand years.

The foundation of all this calculation is, of course, a knowledge of the length of time the *Crania* and the coralline needed to attain their full size; and, on this head, precise knowledge is at present wanting. But there are circumstances which tend to show that nothing like an inch of chalk has accumulated during the life of a *Crania;* and, on any probable estimate of the length of that life, the chalk period must have had a much longer duration than that thus roughly assigned to it.

Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom, but it is no less

certain that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began, or ended, its existence is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made in various parts of Western Europe of flint implements, obviously worked into shape by human hands, under circumstances which show conclusively that man is a very ancient denizen of these regions.

It has been proved that the old populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days

different from what it is now — the river Somme, for instance, having cut its bed a hundred feet deeper between that time and this; and it is probable that the climate was more like that of Canada or Siberia than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne or of Amiens are to them, as they are to us, in point of antiquity.

But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or boulder clay,° which, in comparison with the chalk, is but a very juvenile deposit. You need go no farther than your own sea-board for evidence of this fact. At one of the most charming spots on the coast of Norfolk, Cromer, you will see the boulder clay forming a vast mass, which lies upon the chalk and must consequently have come

into existence after it. Huge boulders of chalk are, in fact, included in the clay, and have evidently been brought to the position they now occupy, by the same agency as that which has planted blocks of syenite from Norway side by side with them.

The chalk, then, is certainly older than the boulder clay. If you ask how much, I will again take you no farther than the same spot upon your own coasts for evidence. I have spoken of the boulder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer containing vegetable matter. But that layer tells a wonderful history. It is full of stumps of trees, standing as they grew. Fir trees are there with their cones, and hazel-bushes with their nuts; there stand the stools of oak and yew trees, beeches and alders. Hence this stratum is appropriately called the "forest-bed."

It is obvious that the chalk must have been upheaved and converted into dry land before the timber trees could grow upon it. As the bolls of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed re-

mained in the same condition for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn.

When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these great grinders crunch, in the dark woods of which the forest-bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree-stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game whose spoils have rejoiced your geologists. How long it remained in that condition cannot be said, but "the whirligig of time brought its revenges" in those days as in

these. That dry land, with the bones and teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and boulder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among the topmost twigs of the fir trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more, the wolf and the beaver replaced the reindeer and the elephant, and at length what we call the history of England dawned.

Thus you have, within the limits of your own county, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind. But we may go further and demonstrate, by evidence of the same authority as that which testifies to the existence of the father of men, that the chalk is vastly older than Adam himself.

The Book of Genesis informs us that Adam, im-

mediately upon his creation, and before the appearance of Eve, was placed in the Garden of Eden. The problem of the geographical position of Eden has greatly vexed the spirits of the learned in such matters, but there is one point respecting which, so far as I know, no commentator has ever raised a doubt. This is, that of the four rivers which are said to run out of it, Euphrates and Hiddekel° are identical with the rivers now known by the names of Euphrates and Tigris.

But the whole country in which these mighty rivers take their origin, and through which they run, is composed of rocks which are either of the same age as the chalk or of later date. So that the chalk must not only have been formed, but, after its formation, the time required for the deposit of these later rocks and for their upheaval into dry land must have elapsed before the smallest brook which feeds the swift stream of "the great river, the river of Babylon,"° began to flow.

Thus, evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity,

compels you to believe that the earth, from the time of the chalk to the present day, has been the theatre of a series of changes as vast in their amount as they were slow in their progress. The area on which we stand has been first sea and then land, for at least four alternations; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch," not one of the present great physical features of the globe was in existence. Our great mountain ranges, Pyrenees, Alps, Himalayas, Andes, have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai° and Ararat.°

All this is certain, because rocks of cretaceous, or still later, date have shared in the elevatory movements which gave rise to these mountain chains, and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though in Norfolk the forest-bed rests directly upon the chalk, yet it does so, not because the period at which the

forest grew immediately followed that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants.

All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those which now live. Certainly not one of the higher animals was of the same species as any of those now in existence. The beasts

of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely farther back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia° before it was colonized. We should see mammals, birds, reptiles, fishes, insects, snails, and the like, clearly recognizable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present the population of the world has undergone slow and gradual, but incessant, changes. There has been no grand catastrophe — no destroyer has swept away the forms of life of one period, and replaced them by a totally new creation; but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led

from one to the other by the most gradual progress, if we follow the course of Nature through the whole series of those relics of her operations which she has left behind.

And it is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms of life.

Thus the chalk contains remains of those strange flying and swimming reptiles, the pterodactyl,° the ichthyosaurus, and the plesiosaurus, which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

But, amongst these fading remainders of a previous state of things are some very modern forms of life, looking like Yankee pedlers among a tribe of red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living shell-

fish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species, from those which existed at that remote epoch. The *Globigerina* of the present day, for example, is not different specifically from that of the chalk; and the same may be said of many other *Foraminifera*. I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity; but the only example which I can at present give confidently is the snake's-head lamp-shell (*Terebratulina caput serpentis*), which lives in our English seas and abounded (as *Terebratulina striata* of authors) in the chalk.

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shell-fish. We Englishmen are proud to have an ancestor who was present at the battle of Hastings.° The ancestors of *Terebratulina caput serpentis* may have been present at a battle of *Ichthyosauria* in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. While all around has changed, this *Terebratulina*

has peacefully propagated its species from generation to generation, and stands to this day as a living testimony to the continuity of the present with the past history of the globe.

Up to this moment I have stated, so far as I know, nothing but well-authenticated facts, and the immediate conclusions which they force upon the mind.

But the mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation.

Taking the many changes of any given spot of the earth's surface, from sea to land and from land to sea, as an established fact, we cannot refrain from asking ourselves how these changes have occurred. And when we have explained them — as they must be explained — by the alternate slow movements of elevation and depression which have affected the crust of the earth, we go still farther back and ask, Why these movements?

I am not certain that any one can give you a satisfactory answer to that question. Assuredly I

cannot. All that can be said, for certain, is, that such movements are part of the ordinary course of nature, inasmuch as they are going on at the present time. Direct proof may be given that some parts of the land of the northern hemisphere are at this moment insensibly rising and others insensibly sinking; and there is indirect but perfectly satisfactory proof that an enormous area now covered by the Pacific has been deepened thousands of feet since the present inhabitants of that sea came into existence.

Thus there is not a shadow of a reason for believing that the physical changes of the globe, in past times, have been effected by other than natural causes.

Is there any more reason for believing that the concomitant modifications in the forms of the living inhabitants of the globe have been brought about in other ways?

Before attempting to answer this question, let us try to form a distinct mental picture of what has happened in some special case.

The crocodiles are animals which, as a group, have a very vast antiquity. They abounded ages before

the chalk was deposited; they throng the rivers in warm climates at the present day. There is a difference in the form of the joints of the backbone and in some minor particulars between the crocodiles of the present epoch and those which lived before the chalk; but, in the cretaceous epoch, as I have already mentioned, the crocodiles had assumed the modern type of structure. Notwithstanding this, the crocodiles of the chalk are not identically the same as those which lived in the times called "old tertiary," which succeeded the cretaceous epoch; and the crocodiles of the older tertiaries are not identical with those of the newer tertiaries, nor are these identical with existing forms. I leave open the question whether particular species may have lived on from epoch to epoch. But each epoch has had its peculiar crocodiles; though all, since the chalk, have belonged to the modern type, and differ simply in their proportions, and in such structural particulars as are discernible only to trained eyes.

How is the existence of this long succession of different species of crocodiles to be accounted for?

Only two suppositions seem to be open to us — either each species of crocodile has been specially

created, or it has arisen out of some preëxisting form by the operation of natural causes.

Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense in the simple words in which the writer of Genesis records the proceedings of the fifth and sixth days of the Creation.

On the other hand, I see no good reason for doubting the necessary alternative, that all these varied species have been evolved from preëxisting crocodilian forms, by the operation of causes as completely a part of the common order of nature as those which have effected the changes of the inorganic world.

Few will venture to affirm that the reasoning which applies to crocodiles loses its force among other animals or among plants. If one series of species has come into existence by the operation of natural causes, it seems folly to deny that all may have arisen in the same way.

A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this physical metamorphosis is no false image of what has been the result of our subjecting it to a jet of fervent, though nowise brilliant, thought to-night. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting "without haste, but without rest" ° of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

V

ON THE EDUCATIONAL VALUE OF THE NATURAL HISTORY SCIENCES

THE subject to which I have to beg your attention during the ensuing hour is "The Relation of Physiological Science to Other Branches of Knowledge."

Had circumstances permitted of the delivery, in their strict logical order, of that series of discourses of which the present lecture is a member, I should have preceded my friend and colleague, Mr. Henfrey, who addressed you on Monday last; but while, for the sake of that order, I must beg you to suppose that this discussion of the educational bearings of biology in general *does* precede that of special zoölogy and botany, I am rejoiced to be able to take advantage of the light thus already thrown upon the tendency and methods of physiological science.

Regarding physiological science, then, in its widest sense — as the equivalent of *biology* — the

science of individual life — we have to consider in succession: —

1. Its position and scope as a branch of knowledge.

2. Its value as a means of mental discipline.

3. Its worth as practical information.

And lastly,

4. At what period it may best be made a branch of education.

Our conclusions on the first of these heads must depend, of course, upon the nature of the subject-matter of biology; and I think a few preliminary considerations will place before you in a clear light the vast difference which exists between the living bodies with which physiological science is concerned and the remainder of the universe; between the phenomena of number and space, of physical and of chemical force, on the one hand, and those of Life, on the other.

The mathematician, the physicist, and the chemist contemplate things in a condition of rest; they look upon a state of equilibrium as that to which all bodies normally tend.

The mathematician does not suppose that a quan-

tity will alter, or that a given point in space will change its direction with regard to another point, spontaneously. And it is the same with the physicist. When Newton° saw the apple fall, he concluded at once that the act of falling was not the result of any power inherent in the apple, but that it was the result of the action of something else on the apple. In a similar manner, all physical force is regarded as the disturbance of an equilibrium to which things tended before its exertion, — to which they will tend again after its cessation.

The chemist equally regards chemical change in a body, as the effect of the action of something external to the body changed. A chemical compound once formed would persist forever, if no alteration took place in surrounding conditions.

But to the student of Life the aspect of Nature is reversed. Here, incessant and, so far as we know, spontaneous change is the rule, rest the exception — the anomaly to be accounted for. Living things have no inertia, and tend to no equilibrium.

Permit me, however, to give more force and clearness to these somewhat abstract considerations by an illustration or two.

Imagine a vessel full of water, at the ordinary temperature, in an atmosphere saturated with vapour. The *quantity* and the *figure* of that water will not change, so far as we know, forever.

Suppose a lump of gold be thrown into the vessel — motion and disturbance of figure exactly proportional to the momentum of the gold will take place. But after a time the effects of this disturbance will subside — equilibrium will be restored, and the water will return to its passive state.

Expose the water to cold — it will solidify, and in so doing its particles will arrange themselves in definite crystalline shapes. But once formed, these crystals change no further.

Again, substitute for the lump of gold some substance capable of entering into chemical relations with the water; say, a mass of that substance which is called "protein," the substance of flesh: a very considerable disturbance of equilibrium will take place — all sorts of chemical compositions and decompositions will occur; but in the end, as before, the result will be the resumption of a condition of rest.

Instead of such a mass of *dead* protein, however,

take a particle of *living* protein — one of those minute microscopic living things which throng our pools, and are known as *Infusoria*,[°] such a creature, for instance, as an *Euglena*, and place it in our vessel of water. It is a round mass provided with a long filament, and except in this peculiarity of shape presents no appreciable physical or chemical difference whereby it might be distinguished from the particle of dead protein.

But the difference in the phenomena to which it will give rise is immense: in the first place it will develop a vast quantity of physical force — cleaving the water in all directions with considerable rapidity by means of the vibrations of the long filament or cilium.

Nor is the amount of chemical energy which the little creature possesses less striking. It is a perfect laboratory in itself, and it will act and react upon the water and the matters contained therein, converting them into new compounds resembling its own substance, and at the same time giving up portions of its own substance which have become effete.

Furthermore, the *Euglena* will increase in size;

but this increase is by no means unlimited, as the increase of a crystal might be. After it has grown to a certain extent it divides, and each portion assumes the form of the original, and proceeds to repeat the process of growth and division.

Nor is this all. For after a series of such divisions and subdivisions these minute points assume a totally new form, lose their long tails, round themselves, and secrete a sort of envelope or box, in which they remain shut up for a time, eventually to resume, directly or indirectly, their primitive mode of existence.

Now, so far as we know, there is no natural limit to the existence of the *Euglena*, or of any other living germ. A living species once launched into existence tends to live forever.

Consider how widely different this living particle is from the dead atoms with which the physicist and chemist have to do!

The particle of gold falls to the bottom and rests — the particle of dead protein decomposes and disappears — it also rests; but the *living* protein mass neither tends to exhaustion of its forces nor to any permanency of form, but is essentially distinguished

as a disturber of equilibrium so far as force is concerned, — as undergoing continual metamorphosis and change, in point of form.

Tendency to equilibrium of force and to permanency of form, then, are the characters of that portion of the universe which does not live — the domain of the chemist and physicist.

Tendency to disturb existing equilibrium — to take on forms which succeed one another in definite cycles — is the character of the living world.

What is the cause of this wonderful difference between the dead particle and the living particle of matter appearing in other respects identical — that difference to which we give the name of Life?

I for one cannot tell you. It may be that by and by philosophers will discover some higher laws of which the facts of life are particular cases — very possibly they will find out some bond between physico-chemical phenomena, on the one hand, and vital phenomena, on the other. At present, however, we assuredly know of none; and I think we shall exercise a wise humility in confessing that, for us at least, this successive assumption of different states (external conditions remaining the same),

this *spontaneity of action*, — if I may use a term which implies more than I would be answerable for, — which constitutes so vast and plain a practical distinction between living bodies and those which do not live, is an ultimate fact; indicating as such the existence of a broad line of demarcation between the subject-matter of biological and that of all other sciences.

For I would have it understood that this simple *Euglena* is the type of *all* living things, so far as the distinction between these and inert matter is concerned. That cycle of changes, which is constituted by perhaps not more than two or three steps in the *Euglena*, is as clearly manifested in the multitudinous stages through which the germ of an oak or of a man passes. Whatever forms the Living Being may take on, whether simple or complex, *production*, *growth*, *reproduction*, are the phenomena which distinguish it from that which does not live.

If this be true, it is clear that the student, in passing from the physico-chemical to the physiological sciences, enters upon a totally new order of facts; and it will next be for us to consider how far these new facts involve *new* methods, or require a modifi-

cation of those with which he is already acquainted. Now a great deal is said about the peculiarity of the scientific method in general, and of the different methods which are pursued in the different sciences. The mathematics are said to have one special method, physics another, biology a third, and so forth. For my own part, I must confess that I do not understand this phraseology.

So far as I can arrive at any clear comprehension of the matter, Science is not, as many would seem to suppose, a modification of the black art, suited to the tastes of the nineteenth century, and flourishing mainly in consequence of the decay of the *Inquisition.*°

Science is, I believe, nothing but *trained and organized common sense*, differing from the latter only as a veteran may differ from a raw recruit; and its methods differ from those of common sense only so far as the guardsman's cut and thrust differ from the manner in which a savage wields his club. The primary power is the same in each case, and perhaps the untutored savage has the more brawny arm of the two. The *real* advantage lies in the point and polish of the swordsman's weapon, in the trained

eye quick to spy out the weakness of the adversary, in the ready hand prompt to follow it on the instant. But, after all, the sword exercise is only the hewing and poking of the clubman developed and perfected.

So, the vast results obtained by Science are won by no mystical faculties, by no mental processes, other than those which are practised by every one of us, in the humblest and meanest affairs of life. A detective policeman discovers a burglar from the marks made by his shoe, by a mental process identical with that by which Cuvier° restored the extinct animals of Montmartre from fragments of their bones. Nor does that process of induction and deduction by which a lady, finding a stain of a peculiar kind upon her dress, concludes that somebody has upset the inkstand thereon, differ in any way, in kind, from that by which Adams° and Leverrier° discovered a new planet.

The man of science, in fact, simply uses with scrupulous exactness the methods which we all, habitually and at every moment, use carelessly; and the man of business must as much avail himself of the scientific method — must be as truly a man of science — as the veriest bookworm of us all; though I have

no doubt that the man of business will find himself out to be a philosopher with as much surprise as M. Jourdain° exhibited when he discovered that he had been all his life talking prose. If, however, there be no real difference between the methods of science and those of common life, it would seem, on the face of the matter, highly improbable that there should be any difference between the methods of the different sciences; nevertheless, it is constantly taken for granted that there is a very wide difference between the physiological and other sciences in point of method.

In the first place it is said — and I take this point first, because the imputation is too frequently admitted by physiologists themselves — that biology differs from the physico-chemical and mathematical sciences in being "inexact."

Now, this phrase "inexact" must refer either to the *methods* or to the *results* of physiological science. It cannot be correct to apply it to the methods; for, as I hope to show you by and by, these are identical in all sciences, and whatever is true of physiological method is true of physical and mathematical method.

Is it then the *results* of biological science which are "inexact"? I think not. If I say that respiration is performed by the lungs; that digestion is effected in the stomach; that the eye is the organ of sight; that the jaws of a vertebrated animal never open sideways, but always up and down; while those of an annulose° animal always open sideways, and never up and down — I am enumerating propositions which are as exact as anything in Euclid.° How, then, has this notion of the inexactness of biological science come about? I believe from two causes: first, because, in consequence of the great complexity of the science and the multitude of interfering conditions, we are very often only enabled to predict approximately what will occur under given circumstances; and secondly, because, on account of the comparative youth of the physiological sciences, a great many of their laws are still imperfectly worked out. But, in an educational point of view, it is most important to distinguish between the essence of a science and the accidents which surround it; and essentially, the methods and results of physiology are as exact as those of physics or mathematics.

It is said that the physiological method is especially *comparative;* and this dictum also finds favour in the eyes of many. I should be sorry to suggest that the speculators on scientific classification have been misled by the accident of the name of one leading branch of biology — *Comparative Anatomy*°; but I would ask whether *comparison*, and that classification which is the result of comparison, are not the essence of every science whatsoever? How is it possible to discover a relation of cause and effect of *any* kind without comparing a series of cases together in which the supposed cause and effect occur singly or combined? So far from comparison being in any way peculiar to biological science, it is, I think, the essence of every science.

A speculative philosopher again tells us that the biological sciences are distinguished by being sciences of observation and not of experiment!

Of all the strange assertions into which speculation without practical acquaintance with a subject may lead even an able man, I think this is the very strangest. Physiology not an experimental science! Why, there is not a function of a single organ in the body which has not been determined wholly and

solely by experiment. How did Harvey[°] determine the nature of the circulation except by experiment? How did Sir Charles Bell[°] determine the functions of the roots of the spinal nerves save by experiment? How do we know the use of a nerve at all except by experiment? Nay, how do you know even that your eye is your seeing apparatus, unless you make the experiment of shutting it; or that your ear is your hearing apparatus, unless you close it up and thereby discover that you become deaf?

It would really be much more true to say that physiology is *the* experimental science *par excellence* of all sciences; that in which there is least to be learned by mere observation, and that which affords the greatest field for the exercise of those faculties which characterize the experimental philosopher. I confess, if any one were to ask me for a model application of the logic of experiment, I should know no better work to put into his hands than Bernard's[°] late "Researches on the Functions of the Liver."

Not to give this lecture a too controversial tone, however, I must only advert to one more doctrine, held by a thinker of our own age and country,

whose opinions are worthy of all respect. It is that the biological sciences differ from all others, inasmuch as in *them* classification takes place by type and not by definition.

It is said, in short, that a natural history class is not capable of being defined — that the class *Rosaceæ*,° for instance, or the class of Fishes, is not accurately and absolutely definable, inasmuch as its members will present exceptions to every possible definition; and that the members of the class are united together only by the circumstance that they are all more like some imaginary average rose or average fish than they resemble anything else.

But here, as before, I think the distinction has arisen entirely from confusing a transitory imperfection with an essential character. So long as our information concerning them is imperfect, we class all objects together according to resemblances which we *feel*, but cannot *define;* we group them round *types*, in short. Thus, if you ask an ordinary person what kinds of animals there are, he will probably say beasts, birds, reptiles, fishes, insects, etc. Ask him to define a beast from a reptile, and he cannot do it; but he says things like a cow or a

horse are beasts, and things like a frog or a lizard are reptiles. You see *he does* class by type, and not by definition. But how does this classification differ from that of the scientific zoölogist? How does the meaning of the scientific class name of *Mammalia* differ from the unscientific of Beasts?

Why, exactly because the former depends on a definition, the latter on a type. The class *Mammalia* is scientifically defined as "all animals which have a vertebrated skeleton and suckle their young." Here is no reference to type, but a definition rigorous enough for a geometrician. And such is the character which every scientific naturalist recognizes as that to which his classes must aspire — knowing, as he does, that classification by type is simply an acknowledgment of ignorance and a temporary device.

So much in the way of negative argument as against the reputed differences between biological and other methods. No such differences, I believe, really exist. The subject-matter of biological science is different from that of other sciences, but the methods of all are identical; and these methods are: —

1. *Observation* of facts — including under this head that *artificial observation* which is called *experiment.*

2. That process of tying up similar facts into bundles, ticketed and ready for use, which is called *comparison* and *classification,* — the results of the process, the ticketed bundles, being named *general propositions.*

3. *Deduction,* which takes us from the general proposition to facts again, teaches us, if I may so say, to anticipate from the ticket what is inside the bundle. And finally —

4. *Verification,* which is the process of ascertaining whether, in point of fact, our anticipation is a correct one.

Such are the methods of all science whatsoever; but perhaps you will permit me to give you an illustration of their employment in the science of Life; and I will take as a special case the establishment of the doctrine of the *circulation of the blood.*

In this case, *simple observation* yields us a knowledge of the existence of the blood from some accidental hemorrhage, we will say: we may even grant that it informs us of the localization of this

blood in particular vessels, the heart, etc., from some accidental cut or the like. It teaches also the existence of a pulse in various parts of the body, and acquaints us with the structure of the heart and vessels.

Here, however, *simple observation* stops, and we must have recourse to *experiment.*

You tie a vein, and you find that the blood accumulates on the side of the ligature opposite the heart. You tie an artery, and you find that the blood accumulates on the side near the heart. Open the chest, and you see the heart contracting with great force. Make openings into its principal cavities, and you will find that all the blood flows out, and no more pressure is exerted on either side of the arterial or venous ligature.

Now all these facts, taken together, constitute the evidence that the blood is propelled by the heart through the arteries, and returns by the veins — that, in short, the blood circulates.

Suppose our experiments and observations have been made on horses, then we group and ticket them into a general proposition, thus: ***all horses have a circulation of their blood.***

Henceforward a horse is a sort of indication or label, telling us where we shall find a peculiar series of phenomena called the circulation of the blood.

Here is our *general proposition*, then.

How and when are we justified in making our next step — a *deduction* from it?

Suppose our physiologist, whose experience is limited to horses, meets with a zebra for the first time, — will he suppose that this generalization holds good for zebras, also?

That depends very much on his turn of mind. But we will suppose him to be a bold man. He will say, "The zebra is certainly not a horse, but it is very like one, — so like that it must be the 'ticket' or mark of a blood circulation also; and I conclude that the zebra has a circulation."

That is a deduction, a very fair deduction, but by no means to be considered scientifically secure. This last quality, in fact, can only be given by *verification* — that is, by making a zebra the subject of all the experiments performed on the horse. Of course, in the present case the *deduction* would be *confirmed* by this process of verification, and the result would be, not merely a positive widening of

knowledge, but a fair increase of confidence in the truth of one's generalizations in other cases.

Thus, having settled the point in the zebra and horse, our philosopher would have great confidence in the existence of a circulation in the ass. Nay, I fancy most persons would excuse him, if in this case he did not take the trouble to go through the process of verification at all; and it would not be without a parallel in the history of the human mind, if our imaginary physiologist now maintained that he was acquainted with asinine circulation *a priori*.

However, if I might impress any caution upon your minds, it is the utterly conditional nature of all our knowledge, — the danger of neglecting the process of verification under any circumstances, and the film upon which we rest the moment our deductions carry us beyond the reach of this great process of verification. There is no better instance of this than is afforded by the history of our knowledge of the circulation of the blood in the animal kingdom until the year 1824. In every animal possessing a circulation at all, which had been observed up to that time, the current of the blood was known to take one definite and invariable di-

rection. Now there is a class of animals called *Ascidians*,° which possess a heart and a circulation, and up to the period of which I speak no one would have dreamed of questioning the propriety of the deduction, that these creatures have a circulation in one direction; nor would any one have thought it worth while to verify the point. But in that year M. von Hasselt, happening to examine a transparent animal of this class, found, to his infinite surprise, that after the heart had beat a certain number of times it stopped, and then began beating the opposite way — so as to reverse the course of the current, which returned by and by to its original direction.

I have myself timed the heart of these little animals. I found it as regular as possible in its periods of reversal; and I know no spectacle in the animal kingdom more wonderful than that which it presents — all the more wonderful that to this day it remains an unique fact, peculiar to this class among the whole animated world. At the same time I know of no more striking case of the necessity of the *verification* of even those deductions which seem founded on the widest and safest inductions.

Such are the methods of biology — methods which are obviously identical with those of all other sciences, and therefore wholly incompetent to form the ground of any distinction between it and them.

But I shall be asked at once, Do you mean to say that there is no difference between the habit of mind of a mathematician and that of a naturalist? Do you imagine that Laplace° might have been put into the Jardin des Plantes,° and Cuvier° into the Observatory, with equal advantage to the progress of the sciences they professed?

To which I would reply, that nothing could be farther from my thoughts. But different habits and various special tendencies of two sciences do not imply different methods. The mountaineer and the man of the plains have very different habits of progression, and each would be at a loss in the other's place; but the method of progression, by putting one leg before the other, is the same in each case. Every step of each is a combination of a lift and a push; but the mountaineer lifts more and the lowlander pushes more. And I think the case of two sciences resembles this.

I do not question for a moment that while the

mathematician is busied with deductions *from* general propositions, the biologist is more especially occupied with observation, comparison, and those processes which lead *to* general propositions. All I wish to insist upon is that this difference depends not on any fundamental distinction in the sciences themselves, but on the accidents of their subject-matter, of their relative complexity, and consequent relative perfection.

The mathematician deals with two properties of objects only, number and extension, and all the inductions he wants have been formed and finished ages ago. He is occupied now with nothing but deduction and verification.

The biologist deals with a vast number of properties of objects, and his inductions will not be completed, I fear, for ages to come; but when they are, his science will be as deductive and as exact as the mathematics themselves.

Such is the relation of biology to those sciences which deal with objects having fewer properties than itself. But as the student, in reaching biology, looks back upon sciences of a less complex and therefore more perfect nature, so, on the other hand,

does he look forward to other more complex and less perfect branches of knowledge. Biology deals only with living beings as isolated things — treats only of the life of the individual; but there is a higher division of science still, which considers living beings as aggregates — which deals with the relation of living beings one to another — the science which *observes* men — whose *experiments* are made by nations one upon another, in battle-fields — whose *general propositions* are embodied in history, morality, and religion — whose *deductions* lead to our happiness or our misery, — and whose *verifications* so often come too late, and serve only

"To point a moral or adorn a tale," ° —

I mean the science of Society or *Sociology*.

I think it is one of the grandest features of biology that it occupies this central position in human knowledge. There is no side of the human mind which physiological study leaves uncultivated. Connected by innumerable ties with abstract science, Physiology is yet in the most intimate relation with humanity; and by teaching us that law and order, and a definite scheme of development, regulate

even the strangest and wildest manifestations of individual life, she prepares the student to look for a goal even amidst the erratic wanderings of mankind, and to believe that history offers something more than an entertaining chaos — a journal of a toilsome, tragi-comic march nowhither.

The preceding considerations have, I hope, served to indicate the replies which befit the two first of the questions which I set before you at starting, viz. What is the range and position of physiological science as a branch of knowledge, and What is its value as a means of mental discipline?

Its *subject-matter* is a large moiety of the universe; its *position* is midway between the physico-chemical and the social sciences. Its *value* as a branch of discipline is partly that which it has in common with all sciences — the training and strengthening of common sense; partly that which is more peculiar to itself — the great exercise which it affords to the faculties of observation and comparison; and I may add, the *exactness* of knowledge which it requires on the part of those among its votaries who desire to extend its boundaries.

If what has been said as to the position and scope

of biology be correct, our third question — What is the practical value of physiological instruction? — might, one would think, be left to answer itself.

On other grounds even, were mankind deserving of the title "rational," which they arrogate to themselves, there can be no question that they would consider, as the most necessary of all branches of instruction for themselves and for their children, that which professes to acquaint them with the conditions of the existence they prize so highly — which teaches them how to avoid disease and to cherish health in themselves and those who are dear to them.

I am addressing, I imagine, an audience of educated persons; and yet I dare venture to assert that, with the exception of those of my hearers who may chance to have received a medical education, there is not one who could tell me what is the meaning and use of an act which he performs a score of times every minute, and whose suspension would involve his immediate death, — I mean the act of breathing, — or who could state in precise terms why it is that a confined atmosphere is injurious to health.

The *practical value* of physiological knowledge!

Why is it that educated men can be found to maintain that a slaughter-house in the midst of a great city is rather a good thing than otherwise? — that mothers persist in exposing the largest possible amount of surface of their children to the cold by the absurd style of dress they adopt, and then marvel at the peculiar dispensation of Providence, which removes their infants by bronchitis and gastric fever? Why is it that quackery rides rampant over the land; and that not long ago, one of the largest public rooms in this great city could be filled by an audience gravely listening to the reverend expositor of the doctrine — that the simple physiological phenomena known as spirit-rapping, table-turning, phreno-magnetism, and by I know not what other absurd and inappropriate names, are due to the direct and personal agency of Satan°?

Why is all this, except from the utter ignorance as to the simplest laws of their own animal life, which prevails among even the most highly educated persons in this country?

But there are other branches of biological science, besides physiology proper, whose practical influence, though less obvious, is not, as I believe, less certain.

I have heard educated men speak with an ill-disguised contempt of the studies of the naturalist, and ask, not without a shrug, "What is the use of knowing all about these miserable animals — what bearing has it on human life?"

I will endeavour to answer that question. I take it that all will admit there is definite government of this universe — that its pleasures and pains are not scattered at random, but are distributed in accordance with orderly and fixed laws, and that it is only in accordance with all we know of the rest of the world, that there should be an agreement between one portion of the sensitive creation and another in these matters.

Surely, then, it interests us to know the lot of other animal creatures — however far below us, they are still the sole created things which share with us the capability of pleasure and the susceptibility to pain.

I cannot but think that he who finds a certain proportion of pain and evil inseparably woven up in the life of the very worms will bear his own share with more courage and submission; and will, at any rate, view with suspicion those weakly amiable theories of the Divine government, which would

have us believe pain to be an oversight and a mistake — to be corrected by and by. On the other hand, the predominance of happiness among living things, — their lavish beauty, — the secret and wonderful harmony which pervades them all, from the highest to the lowest, are equally striking refutations of that modern Manichean doctrine,° which exhibits the world as a slave-mill, worked with many tears, for mere utilitarian ends.

There is yet another way in which natural history may, I am convinced, take a profound hold upon practical life, — and that is by its influence over our finer feelings, as the greatest of all sources of that pleasure which is derivable from beauty. I do not pretend that natural history knowledge, as such, can increase our sense of the beautiful in natural objects. I do not suppose that the dead soul of Peter Bell, of whom the great poet of nature says, —

> "A primrose by the river's brim,
> A yellow primrose was to him, —
> And it was nothing more." °, —

would have been a whit roused from its apathy by the information that the primrose is a *Dicotyledonous Exogen*, with a monopetalous corolla and

central placentation. But I advocate natural history knowledge from this point of view, because it would lead us to *seek* the beauties of natural objects, instead of trusting to chance to force them on our attention. To a person uninstructed in natural history, his country or sea-side stroll is a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall. Teach him something of natural history, and you place in his hands a catalogue of those which are worth turning round. Surely our innocent pleasures are not so abundant in this life that we can afford to despise this or any other source of them. We should fear being banished for our neglect to that limbo, where the great Florentine° tells us are those who, during this life, "wept when they might be joyful."

But I shall be trespassing unwarrantably on your kindness, if I do not proceed at once to my last point — the time at which physiological science should first form a part of the curriculum of education.

The distinction between the teaching of the facts of a science as instruction, and the teaching it sys-

tematically as knowledge, has already been placed before you in a previous lecture; and it appears to me, that, as with other sciences, the *common facts* of biology — the uses of parts of the body — the names and habits of the living creatures which surround us — may be taught with advantage to the youngest child. Indeed, the avidity of children for this kind of knowledge, and the comparative ease with which they retain it, is something quite marvellous. I doubt whether any toy would be so acceptable to young children as a vivarium of the same kind as, but of course on a smaller scale than, those admirable devices in the Zoölogical Gardens.

On the other hand, systematic teaching in biology cannot be attempted with success until the student has attained to a certain knowledge of physics and chemistry; for though the phenomena of life are dependent neither on physical nor on chemical, but on vital forces, yet they result in all sorts of physical and chemical changes which can only be judged by their own laws.

And now to sum up in a few words the conclusions to which I hope you see reason to follow me.

Biology needs no apologist when she demands a

place — and a prominent place — in any scheme of education worthy of the name. Leave out the physiological sciences from your curriculum, and you launch the student into the world, undisciplined in that science whose subject-matter would best develop his powers of observation; ignorant of facts of the deepest importance for his own and others' welfare; blind to the richest sources of beauty in God's creation; and unprovided with that belief in a living law, and an order manifesting itself in and through endless change and variety, which might serve to check and moderate that phase of despair through which, if he take an earnest interest in social problems, he will assuredly sooner or later pass.

Finally, one word for myself. I have not hesitated to speak strongly where I have felt strongly, and I am but too conscious that the indicative and imperative moods have too often taken the place of the more becoming subjunctive and conditional. I feel, therefore, how necessary it is to beg you to forget the personality of him who has thus ventured to address you, and to consider only the truth or error in what has been said.

VI

ON THE STUDY OF ZOÖLOGY

NATURAL History is the name familiarly applied to the study of the properties of such natural bodies as minerals, plants, and animals; the sciences which embody the knowledge man has acquired upon these subjects are commonly termed natural sciences, in contradistinction to other so-called "physical" sciences; and those who devote themselves especially to the pursuit of such sciences have been and are commonly termed "Naturalists."

Linnæus° was a naturalist in this wide sense, and his *Systema Naturæ* was a work upon natural history, in the broadest acceptation of the term; in it that great methodizing spirit embodied all that was known in his time of the distinctive characters of minerals, animals, and plants. But the enormous stimulus which Linnæus gave to the investigation of

nature soon rendered it impossible that any one man should write another *Systema Naturæ*, and extremely difficult for any one to become a naturalist such as Linnæus was.

Great as have been the advances made by all the three branches of science of old included under the title of natural history, there can be no doubt that zoölogy and botany have grown in an enormously greater ratio than mineralogy; and hence, as I suppose, the name of "natural history" has gradually become more and more definitely attached to these prominent divisions of the subject, and by "naturalist" people have meant more and more distinctly to imply a student of the structure and functions of living beings.

However this may be, it is certain that the advance of knowledge has gradually widened the distance between mineralogy and its old associates, while it has drawn zoölogy and botany closer together; so that of late years it has been found convenient (and indeed necessary) to associate the sciences which deal with vitality and all its phenomena under the common head of "biology"; and the biologists have come to repudiate any blood-

relationship with their foster-brothers, the mineralogists.

Certain broad laws have a general application throughout both the animal and the vegetable worlds, but the ground common to these kingdoms of nature is not of very wide extent, and the multiplicity of details is so great, that the student of living beings finds himself obliged to devote his attention exclusively either to the one or the other. If he elects to study plants, under any aspect, we know at once what to call him. He is a botanist, and his science is botany. But if the investigation of animal life be his choice, the name generally applied to him will vary according to the kind of animals he studies, or the particular phenomena of animal life to which he confines his attention. If the study of man is his object, he is called an anatomist, or a physiologist, or an ethnologist; but if he dissects animals, or examines into the mode in which their functions are performed, he is a comparative anatomist or comparative physiologist. If he turns his attention to fossil animals, he is a paleontologist. If his mind is more particularly directed to the description, specific discrimination,

classification, and distribution of animals, he is termed a zoölogist.

For the purposes of the present discourse, however, I shall recognize none of these titles save the last, which I shall employ as the equivalent of botanist, and I shall use the term zoölogy as denoting the whole doctrine of animal life, in contradistinction to botany, which signifies the whole doctrine of vegetable life.

Employed in this sense, zoölogy, like botany, is divisible into three great but subordinate sciences, morphology, physiology, and distribution, each of which may, to a very great extent, be studied independently of the other.

Zoölogical morphology is the doctrine of animal form or structure. Anatomy is one of its branches; development is another; while classification is the expression of the relations which different animals bear to one another, in respect of their anatomy and their development.

Zoölogical distribution is the study of animals in relation to the terrestrial conditions which obtain now, or have obtained at any previous epoch of the earth's history.

Zoölogical physiology, lastly, is the doctrine of the functions or actions of animals. It regards animal bodies as machines impelled by certain forces, and performing an amount of work which can be expressed in terms of the ordinary forces of nature. The final object of physiology is to deduce the facts of morphology, on the one hand, and those of distribution, on the other, from the laws of the molecular forces of matter.°

Such is the scope of zoölogy. But if I were to content myself with the enunciation of these dry definitions, I should ill exemplify that method of teaching this branch of physical science which it is my chief business to-night to recommend. Let us turn away, then, from abstract definitions. Let us take some concrete living thing, some animal, the commoner the better, and let us see how the application of common sense and common logic to the obvious facts it presents inevitably leads us into all these branches of zoölogical science.

I have before me a lobster. When I examine it, what appears to be the most striking character it presents? Why, I observe that this part which we call the tail of the lobster is made up of six distinct

hard rings and a seventh terminal piece. If I separate one of the middle rings, say the third, I find it carries upon its under surface a pair of limbs or appendages, each of which consists of a stalk and two terminal pieces. So that I can represent a transverse section of the ring and its appendages upon the diagram board in this way.

If I now take the fourth ring, I find it has the same structure, and so have the fifth and the second; so that in each of these divisions of the tail, I find parts which correspond with one another, a ring and two appendages; and in each appendage a stalk and two end pieces. These corresponding parts are called in the technical language of anatomy "homologous parts." The ring of the third division is the "homologue" of the ring of the fifth, the appendage of the former is the homologue of the appendage of the latter. And, as each division exhibits corresponding parts in corresponding places, we say that all the divisions are constructed upon the same plan. But now let us consider the sixth division. It is similar to, and yet different from, the others. The ring is essentially the same as in the other divisions, but the appendages look at first as if they

were very different; and yet when we regard them closely, what do we find? A stalk and two terminal divisions, exactly as in the others, but the stalk is very short and very thick, the terminal divisions are very broad and flat, and one of them is divided into two pieces.

I may say, therefore, that the sixth segment is like the others in plan, but that it is modified in its details.

The first segment is like the others, so far as its ring is concerned, and though its appendages differ from any of those yet examined in the simplicity of their structure, parts corresponding with the stem and one of the divisions of the appendages of the other segments can be readily discerned in them.

Thus it appears that the lobster's tail is composed of a series of segments which are fundamentally similar, though each presents peculiar modifications of the plan common to all. But when I turn to the fore part of the body, I see, at first, nothing but a great shield-like shell, called technically the "carapace," ending in front in a sharp spine, on either side of which are the curious compound eyes, set upon the ends of stout movable stalks. Behind

these, on the under side of the body, are two pairs of long feelers, or antennæ, followed by six pairs of jaws, folded against one another over the mouth, and five pairs of legs, the foremost of these being the great pinchers, or claws, of the lobster.

It looks, at first, a little hopeless to attempt to find in this complex mass a series of rings, each with its pair of appendages, such as I have shown you in the abdomen, and yet it is not difficult to demonstrate their existence. Strip off the legs, and you will find that each pair is attached to a very definite segment of the under wall of the body; but these segments, instead of being the lower parts of free rings, as in the tail, are such parts of rings which are all solidly united and bound together; and the like is true of the jaws, the feelers, and the eye-stalks, every pair of which is borne upon its own special segment. Thus the conclusion is gradually forced upon us that the body of the lobster is composed of as many rings as there are pairs of appendages, namely, twenty in all, but that the six hindmost rings remain free and movable, while the fourteen front rings become firmly soldered together, their backs forming one continuous shield — the carapace.

Unity of plan, diversity in execution, is the lesson taught by the study of the rings of the body, and the same instruction is given still more emphatically by the appendages. If I examine the outermost jaw, I find it consists of three distinct portions, an inner, a middle, and an outer, mounted upon a common stem; and if I compare this jaw with the legs behind it, or the jaws in front of it, I find it quite easy to see that in the legs it is the part of the appendage which corresponds with the inner division which becomes modified into what we know familiarly as the "leg," while the middle division disappears, and the outer division is hidden under the carapace. Nor is it more difficult to discern that in the appendages of the tail the middle division appears again and the outer vanishes; while, on the other hand, in the foremost jaw, the so-called mandible, the inner division only is left; and in the same way the parts of the feelers and of the eye-stalks can be identified with those of the legs and jaws.

But whither does all this tend? To the very remarkable conclusion that a unity of plan, of the same kind as that discoverable in the tail or abdomen of the lobster, pervades the whole organization

of its skeleton, so that I can return to the diagram representing any one of the rings of the tail, which I drew upon the board, and by adding a third division to each appendage I can use it as a sort of scheme or plan of any ring of the body. I can give names to all the parts of that figure, and then if I take any segment of the body of the lobster, I can point out to you exactly what modification the general plan has undergone in that particular segment; what part has remained movable, and what has become fixed to another; what has been excessively developed and metamorphosed, and what has been suppressed.

But I imagine I hear the question, How is all this to be tested? No doubt it is a pretty and ingenious way of looking at the structure of any animal, but is it anything more? Does Nature acknowledge, in any deeper way, this unity of plan we seem to trace?

The objection suggested by these questions is a very valid and important one, and morphology was in an unsound state so long as it rested upon the mere perception of the analogies which obtain between fully formed parts. The unchecked ingenuity of speculative anatomists proved itself fully

competent to spin any number of contradictory hypotheses out of the same facts, and endless morphological dreams threatened to supplant scientific theory.

Happily, however, there is a criterion of morphological truth, and a sure test of all homologies. Our lobster has not always been what we see it; it was once an egg, a semifluid mass of yolk, not so big as a pin's head, contained in a transparent membrane, and exhibiting not the least trace of any one of those organs, whose multiplicity and complexity in the adult are so surprising. After a time a delicate patch of cellular membrane appeared upon one face of this yolk, and that patch was the foundation of the whole creature, the clay out of which it would be moulded. Gradually investing the yolk, it became subdivided by transverse constrictions into segments, the forerunners of the rings of the body. Upon the ventral surface of each of the rings thus sketched out, a pair of budlike prominences made their appearance — the rudiments of the appendages of the ring. At first, all the appendages were alike, but as they grew, most of them became distinguished into a stem and two terminal divisions, to which, in the

middle part of the body, was added a third outer division; and it was only at a later period that by the modification or absorption of certain of these primitive constituents the limbs acquired their perfect form.

Thus the study of development proves that the doctrine of unity of plan is not merely a fancy, that it is not merely one way of looking at the matter, but that it is the expression of deep-seated natural facts. The legs and jaws of the lobster may not merely be regarded as modifications of a common type, — in fact and in nature they are so, — the leg and the jaw of the young animal being, at first, indistinguishable.

These are wonderful truths, the more so because the zoölogist finds them to be of universal application. The investigation of a polype, of a snail, of a fish, of a horse, or of a man, would have led us, though by a less easy path, perhaps, to exactly the same point. Unity of plan everywhere lies hidden under the mask of diversity of structure — the complex is everywhere evolved out of the simple. Every animal has at first the form of an egg, and every animal and every organic part, in reaching its adult state, passes through conditions common to other

animals and other adult parts; and this leads me to another point. I have hitherto spoken as if the lobster were alone in the world, but, as I need hardly remind you, there are myriads of other animal organisms. Of these some, such as men, horses, birds, fishes, snails, slugs, oysters, corals, and sponges, are not in the least like the lobster. But other animals, though they may differ a good deal from the lobster, are yet either very like it, or are like something that is like it. The crayfish, the rock lobster, and the prawn, and the shrimp, for example, however different, are yet so like lobsters that a child would group them as of the lobster kind, in contradistinction to snails and slugs; and these last again would form a kind by themselves, in contradistinction to cows, horses, and sheep, the cattle kind.

But this spontaneous grouping into "kinds" is the first essay of the human mind at classification, or the calling by a common name of those things that are alike, and the arranging them in such a manner as best to suggest the sum of their likenesses and unlikenesses to other things.

Those kinds which include no other subdivisions than the sexes or various breeds are called in techni-

cal language species. The English lobster is a species, our crayfish is another, our prawn is another. In other countries, however, there are lobsters, crayfish, and prawns very like ours, and yet presenting sufficient differences to deserve distinction. Naturalists, therefore, express this resemblance and this diversity by grouping them as distinct species of the same "genus." But the lobster and the crayfish, though belonging to distinct genera, have many features in common, and hence are grouped together in an assemblage which is called a family. More distant resemblances connect the lobster with the prawn and the crab, which are expressed by putting all these into the same order. Again, more remote, but still very definite, resemblances unite the lobster with the wood-louse, the king crab, the water-flea, and the barnacle, and separate them from all other animals; whence they collectively constitute the larger group or class *Crustacea*. But the *Crustacea* exhibit many peculiar features in common with insects, spiders, and centipedes, so that these are grouped into the still larger assemblage or "province" *Articulata*; and, finally, the relations which these have to worms and other lower animals

are expressed by combining the whole vast aggregate into the sub-kingdom of *Annulosa*.

If I had worked my way from a sponge instead of a lobster, I should have found it associated by like ties with a great number of other animals into the sub-kingdom *Protozoa;* if I had selected a fresh-water polype or a coral, the members of what naturalists term the sub-kingdom *Cœlenterata* would have grouped themselves around my type; had a snail been chosen, the inhabitants of all univalve and bivalve, land and water shells, the lamp-shells, the squids, and the sea-mat would have gradually linked themselves on to it as members of the same sub-kingdom of *Mollusca;* and finally, starting from man, I should have been compelled to admit first the ape, the rat, the horse, the dog, into the same class; and then the bird, the crocodile, the turtle, the frog, and the fish, into the same sub-kingdom of *Vertebrata*.

And if I had followed out all these various lines of classification fully, I should discover in the end that there was no animal, either recent or fossil, which did not at once fall into one or other of these sub-kingdoms. In other words, every animal is organized upon one or other of the five or more plans,

whose existence renders our classification possible. And so definitely and precisely marked is the structure of each animal, that, in the present state of our knowledge, there is not the least evidence to prove that a form, in the slightest degree transitional between any of the two groups *Vertebrata*, *Annulosa*, *Mollusca*, and *Cœlenterata*, either exists, or has existed, during that period of the earth's history which is recorded by the geologist.° Nevertheless, you must not for a moment suppose because no such transitional forms are known, that the members of the sub-kingdoms are disconnected from, or independent of, one another. On the contrary, in their earliest condition they are all alike, and the primordial germs of a man, a dog, a bird, a fish, a beetle, a snail, and a polype are, in no essential structural respects, distinguishable.

In this broad sense it may with truth be said that all living animals, and all those dead creations which geology reveals, are bound together by an all-pervading unity of organization, of the same character, though not equal in degree, to that which enables us to discern one and the same plan amidst the twenty different segments of a lobster's body.

Truly it has been said that to a clear eye the smallest fact is a window through which the Infinite may be seen.

Turning from these purely morphological considerations, let us now examine into the manner in which the attentive study of the lobster impels us into other lines of research.

Lobsters are found in all the European seas; but on the opposite shores of the Atlantic and in the seas of the southern hemisphere they do not exist. They are, however, represented in these regions by very closely allied but distinct forms — the *Homarus Americanus* and the *Homarus Capensis*; so that we may say that the European has one species of *Homarus*; the American another; the African another; and thus the remarkable facts of geographical distribution begin to dawn upon us.

Again, if we examine the contents of the earth's crust, we shall find in the latter of those deposits, which have served as the great burying grounds of past ages, numberless lobster-like animals, but none so similar to our living lobster as to make zoölogists sure that they belonged even to the same genus. If we go still farther back in time, we discover in

the oldest rocks of all the remains of animals, constructed on the same general plan as the lobster, and belonging to the same great group of *Crustacea*, but for the most part totally different from the lobster, and indeed from any other living form of crustacean; and thus we gain a notion of that successive change of the animal population of the globe in past ages, which is the most striking fact revealed by geology.

Consider, now, where our inquiries have led us. We studied our type morphologically when we determined its anatomy and its development, and when comparing it in these respects with other animals, we made out its place in a system of classification. If we were to examine every animal in a similar manner, we should establish a complete body of zoölogical morphology.

Again, we investigated the distribution of our type in space and in time, and if the like had been done with every animal, the sciences of geographical and geological distribution would have attained their limit.

But you will observe one remarkable circumstance, that up to this point the question of the

life of these organisms has not come under consideration. Morphology and distribution might be studied almost as well, if animals and plants were a peculiar kind of crystals, and possessed none of those functions which distinguish living beings so remarkably. But the facts of morphology and distribution have to be accounted for, and the science whose aim it is to account for them is physiology.

Let us return to our lobster once more. If we watched the creature in its native element, we should see it climbing actively the submerged rocks, among which it delights to live, by means of its strong legs; or swimming by powerful strokes of its great tail, the appendages of whose sixth joint are spread out into a broad fanlike propeller; seize it, and it will show you that its great claws are no mean weapons of offence; suspend a piece of carrion among its haunts, and it will greedily devour it, tearing and crushing the flesh by means of its multitudinous jaws.

Suppose that we had known nothing of the lobster but as an inert mass, an organic crystal, if I may use the phrase, and that we could suddenly see it exert-

ing all these powers. What wonderful new ideas and new questions would arise in our minds! The great new question would be, "How does all this take place?" The chief new idea would be, the idea of adaptation to purpose, — the notion, that the constituents of animal bodies are not mere unconnected parts, but organs working together to an end. Let us consider the tail of the lobster again from this point of view. Morphology has taught us that it is a series of segments composed of homologous parts, which undergo various modifications — beneath and through which a common plan of formation is discernible. But if I look at the same part physiologically, I see that it is a most beautifully constructed organ of locomotion, by means of which the animal can swiftly propel itself either backwards or forwards.

But how is this remarkable propulsive machine made to perform its functions? If I were suddenly to kill one of these animals and to take out all the soft parts, I should find the shell to be perfectly inert, to have no more power of moving itself than is possessed by the machinery of a mill when disconnected from its steam-engine or water-wheel. But if I

were to open it, and take out the viscera only, leaving the white flesh, I should perceive that the lobster could bend and extend its tail as well as before. If I were to cut off the tail, I should cease to find any spontaneous motion in it; but on pinching any portion of the flesh, I should observe that it underwent a very curious change — each fibre becoming shorter and thicker. By this act of contraction, as it is termed, the parts to which the ends of the fibre are attached are, of course, approximated; and according to the relations of their points of attachment to the centres of motion of the different rings, the bending or the extension of the tail results. Close observation of the newly opened lobster would soon show that all its movements are due to the same cause — the shortening and thickening of these fleshy fibres, which are technically called muscles.

Here, then, is a capital fact. The movements of the lobster are due to muscular contractility. But why does a muscle contract at one time and not at another? Why does one whole group of muscles contract when the lobster wishes to extend his tail, and another group when he desires to bend it?

What is it originates, directs, and controls the motive power?

Experiment, the great instrument for the ascertainment of truth in physical science, answers this question for us. In the head of the lobster there lies a small mass of that peculiar tissue which is known as nervous substance. Cords of similar matter connect this brain of the lobster, directly or indirectly, with the muscles. Now, if these communicating cords are cut, the brain remaining entire, the power of exerting what we call voluntary motion in the parts below the section is destroyed; and on the other hand, if, the cords remaining entire, the brain mass be destroyed, the same voluntary mobility is equally lost. Whence the inevitable conclusion is that the power of originating these motions resides in the brain, and is propagated along the nervous cords.

In the higher animals the phenomena which attend this transmission have been investigated, and the exertion of the peculiar energy which resides in the nerves has been found to be accompanied by a disturbance of the electrical state of their molecules.°

If we could exactly estimate the signification of

this disturbance; if we could obtain the value of a given exertion of nerve force by determining the quantity of electricity, or of heat, of which it is the equivalent; if we could ascertain upon what arrangement, or other condition of the molecules of matter, the manifestation of the nervous and muscular energies depends (and doubtless science will some day or other ascertain these points),—physiologists would have attained their ultimate goal in this direction; they would have determined the relation of the motive force of animals to the other forms of force found in nature; and if the same process had been successfully performed for all the operations which are carried on in and by the animal frame, physiology would be perfect, and the facts of morphology and distribution would be deducible from the laws which physiologists had established, combined with those determining the condition of the surrounding universe.

There is not a fragment of the organism of this humble animal, whose study would not lead us into regions of thought as large as those which I have briefly opened up to you; but what I have been saying, I trust, has not only enabled you to form a

conception of the scope and purport of zoölogy, but has given you an imperfect example of the manner in which, in my opinion, that science, or indeed any physical science, may be best taught. The great matter is to make teaching real and practical by fixing the attention of the student on particular facts; but at the same time it should be rendered broad and comprehensive by constant reference to the generalizations of which all particular facts are illustrations. The lobster has served as a type of the whole animal kingdom, and its anatomy and physiology have illustrated for us some of the greatest truths of biology. The student who has once seen for himself the facts which I have described, has had their relations explained to him, and has clearly comprehended them, has, so far, a knowledge of zoölogy which is real and genuine, however limited it may be, and which is worth more than all the mere reading knowledge of the science he could ever acquire. His zoölogical information is, so far, knowledge and not mere hearsay.

And if it were my business to fit you for the certificate in zoölogical science granted by this department, I should pursue a course precisely similar

in principle to that which I have taken to-night. I should select a fresh-water sponge, a fresh-water polype or a *Cyanœe*, a fresh-water mussel, a lobster, a fowl, as types of the five primary divisions of the animal kingdom. I should explain their structure very fully, and show how each illustrated the great principles of zoölogy. Having gone very carefully and fully over this ground, I should feel that you had a safe foundation, and I should then take you in the same way, but less minutely, over similarly selected illustrative types of the classes; and then I should direct your attention to the special forms enumerated under the head of types in this syllabus and to the other facts there mentioned.

That would, speaking generally, be my plan. But I have undertaken to explain to you the best mode of acquiring and communicating a knowledge of zoölogy, and you may therefore fairly ask me for a more detailed and precise account of the manner in which I should propose to furnish you with the information I refer to.

My own impression is that the best model for all kinds of training in physical science is that afforded by the method of teaching anatomy in use in the

medical schools. This method consists of three elements — lectures, demonstrations, and examinations.

The object of lectures is, in the first place, to awaken the attention and excite the enthusiasm of the student; and this, I am sure, may be effected to a far greater extent by the oral discourse and by the personal influence of a respected teacher than in any other way. Secondly, lectures have the double use of guiding the student to the salient points of a subject, and at the same time forcing him to attend to the whole of it, and not merely to that part which takes his fancy. And lastly, lectures afford the student the opportunity of seeking explanations of those difficulties which will, and indeed ought to, arise in the course of his studies.

But for a student to derive the utmost possible value from lectures, several precautions are needful.

I have a strong impression that the better a discourse is, as an oration, the worse it is as a lecture. The flow of the discourse carries you on without proper attention to its sense; you drop a word or a phrase, you lose the exact meaning for a moment,

and while you strive to recover yourself, the speaker has passed on to something else.

The practice I have adopted of late years, in lecturing to students, is to condense the substance of the hour's discourse into a few dry propositions, which are read slowly and taken down from dictation; the reading of each being followed by a free commentary, expanding and illustrating the proposition, explaining terms, and removing any difficulties that may be attackable in that way, by diagrams made roughly, and seen to grow under the lecturer's hand. In this manner you, at any rate, insure the coöperation of the student to a certain extent. He cannot leave the lecture room entirely empty if the taking of notes is enforced; and a student must be preternaturally dull and mechanical, if he can take notes and hear them properly explained, and yet learn nothing.

What books shall I read? is a question constantly put by the student to the teacher. My reply usually is, "None: write your notes out carefully and fully; strive to understand them thoroughly; come to me for the explanation of anything you cannot understand; and I would rather you did not distract

your mind by reading." A properly composed course of lectures ought to contain fully as much matter as a student can assimilate in the time occupied by its delivery; and the teacher should always recollect that his business is to feed and not to cram the intellect. Indeed, I believe that a student who gains from a course of lectures the simple habit of concentrating his attention upon a definitely limited series of facts, until they are thoroughly mastered, has made a step of immeasurable importance.

But, however good lectures may be, and however extensive the course of reading by which they are followed up, they are but accessories to the great instrument of scientific teaching — demonstration. If I insist unweariedly, nay fanatically, upon the importance of physical science as an educational agent, it is because the study of any branch of science, if properly conducted, appears to me to fill up a void left by all other means of education. I have the greatest respect and love for literature; nothing would grieve me more than to see literary training other than a very prominent branch of education: indeed, I wish that real literary discipline were far more attended to than it is; but I

cannot shut my eyes to the fact that there is a vast difference between men who have had a purely literary, and those who have had a sound scientific, training.

Seeking for the cause of this difference, I imagine I can find it in the fact that in the world of letters learning and knowledge are one, and books are the source of both; whereas in science, as in life, learning and knowledge are distinct, and the study of things, and not of books, is the source of the latter.

All that literature has to bestow may be obtained by reading and by practical exercise in writing and in speaking; but I do not exaggerate when I say that none of the best gifts of science are to be won by these means. On the contrary, the great benefit which a scientific education bestows, whether as training or as knowledge, is dependent upon the extent to which the mind of the student is brought into immediate contact with facts — upon the degree to which he learns the habit of appealing directly to Nature, and of acquiring through his senses concrete images of those properties of things which are, and always will be, but approximatively expressed in human language. Our way of looking

at Nature and of speaking about her varies from year to year; but a fact once seen, a relation of cause and effect once demonstratively apprehended, are possessions which neither change nor pass away, but, on the contrary, form fixed centres, about which other truths aggregate by natural affinity.

Therefore, the great business of the scientific teacher is to imprint the fundamental, irrefragable facts of his science, not only by words upon the mind, but by sensible impressions upon the eye, and ear, and touch of the student, in so complete a manner, that every term used, or law enunciated, should afterwards call up vivid images of the particular structural or other facts which furnished the demonstration of the law or the illustration of the term.

Now this important operation can only be achieved by constant demonstration, which may take place to a certain imperfect extent during a lecture, but which ought also to be carried on independently, and which should be addressed to each individual student, the teacher endeavouring, not so much to show a thing to the learner, as to make him see it for himself.

I am well aware that there are great practical

difficulties in the way of effectual zoölogical demonstrations. The dissection of animals is not altogether pleasant, and requires much time; nor is it easy to secure an adequate supply of the needful specimens. The botanist has here a great advantage; his specimens are easily obtained, are clean and wholesome, and can be dissected in a private house as well as anywhere else; and hence, I believe, the fact, that botany is so much more readily and better taught than its sister science. But, be it difficult or be it easy, if zoölogical science is to be properly studied, demonstration and, consequently, dissection must be had. Without it no man can have a really sound knowledge of animal organization.

A good deal may be done, however, without actual dissection on the student's part by demonstration upon specimens and preparations; and in all probability it would not be very difficult, were the demand sufficient, to organize collections of such objects, sufficient for all the purposes of elementary teaching, at a comparatively cheap rate. Even without these much might be effected if the zoölogical collections which are open to the public were

arranged according to what has been termed the "typical principle"; that is to say, if the specimens exposed to public view were so selected that the public could learn something from them, instead of being, as at present, merely confused by their multiplicity. For example, the grand ornithological gallery at the British Museum contains between two and three thousand species of birds, and sometimes five or six specimens of a species. They are very pretty to look at, and some of the cases are, indeed, splendid; but I will undertake to say that no man but a professed ornithologist has ever gathered much information from the collection. Certainly no one of the tens of thousands of the general public who have walked through that gallery ever knew more about the essential peculiarities of birds when he left the gallery than when he entered it. But if, somewhere in that vast hall, there were a few preparations, exemplifying the leading structural peculiarities and the mode of development of a common fowl; if the types of the genera, the leading modifications in the skeleton, in the plumage at various ages, in the mode of nidification, and the like, among birds, were displayed; and if the

other specimens were put away in a place where the men of science, to whom they are alone useful, could have free access to them, I can conceive that this collection might become a great instrument of scientific education.

The last implement of the teacher to which I have adverted is examination — a means of education now so thoroughly understood that I need hardly enlarge upon it. I hold that both written and oral examinations are indispensable, and, by requiring the description of specimens, they may be made to supplement demonstration.

Such is the fullest reply the time at my disposal will allow me to give to the question — How may a knowledge of zoölogy be best acquired and communicated?

But there is a previous question which may be moved, and which, in fact, I know many are inclined to move. It is the question, Why should training masters be encouraged to acquire a knowledge of this or any other branch of physical science? What is the use, it is said, of attempting to make physical science a branch of primary education? Is it not probable that teachers in pursuing such studies will

be led astray from the acquirement of more important but less attractive knowledge? And, even if they can learn something of science without prejudice to their usefulness, what is the good of their attempting to instil that knowledge into boys whose real business is the acquisition of reading, writing, and arithmetic?

These questions are, and will be, very commonly asked, for they arise from that profound ignorance of the value and true position of physical science which infests the minds of the most highly educated and intelligent classes of the community. But if I did not feel well assured that they are capable of being easily and satisfactorily answered; that they have been answered over and over again; and that the time will come when men of liberal education will blush to raise such questions, — I should be ashamed of my position here to-night. Without doubt it is your great and very important function to carry out elementary education; without question, anything that should interfere with the faithful fulfilment of that duty on your part would be a great evil; and if I thought that your acquirement of the elements of physical science, and

your communication of those elements to your pupils, involved any sort of interference with your proper duties, I should be the first person to protest against your being encouraged to do anything of the kind.

But is it true that the acquisition of such a knowledge of science as is proposed and the communication of that knowledge are calculated to weaken your usefulness? Or may I not rather ask, is it possible for you to discharge your functions properly without these aids?

What is the purpose of primary intellectual education? I apprehend that its first object is to train the young in the use of those tools wherewith men extract knowledge from the ever shifting succession of phenomena which pass before their eyes; and that its second object is to inform them of the fundamental laws which have been found by experience to govern the course of things, so that they may not be turned out into the world naked, defenceless, and a prey to the events they might control.

A boy is taught to read his own and other languages in order that he may have access to infinitely wider stores of knowledge than could ever be opened

to him by oral intercourse with his fellow-men; he learns to write that his means of communication with the rest of mankind may be indefinitely enlarged, and that he may record and store up the knowledge he acquires. He is taught elementary mathematics that he may understand all those relations of number and form, upon which the transactions of men associated in complicated societies are built, and that he may have some practice in deductive reasoning.

All these operations of reading, writing, and ciphering are intellectual tools whose use should, before all things, be learned, and learned thoroughly; so that the youth may be enabled to make his life that which it ought to be, — a continual progress in learning and in wisdom.

But, in addition, primary education endeavours to fit a boy out with a certain equipment of positive knowledge. He is taught the great laws of morality; the religion of his sect; so much history and geography as will tell him where the great countries of the world are, what they are, and how they have become what they are.

Without doubt all these are most fitting and ex-

cellent things to teach a boy; I should be very sorry to omit any of them from any scheme of primary intellectual education. The system is excellent so far as it goes.

But if I regard it closely, a curious reflection arises. I suppose that fifteen hundred years ago the child of any well-to-do Roman citizen was taught just these same things: reading and writing in his own and, perhaps, the Greek tongue; the elements of mathematics; and the religion, morality, history, and geography current in his time. Furthermore, I do not think I err in affirming that if such a Christian Roman boy, who had finished his education, could be transplanted into one of our public schools, and pass through its course of instruction, he would not meet with a single unfamiliar line of thought; amidst all the new facts he would have to learn not one would suggest a different mode of regarding the universe from that current in his own time.

And yet surely there is some great difference between the civilization of the fourth century and that of the nineteenth, and still more between the intellectual habits and tone of thought of that day and this.

And what has made this difference? I answer fearlessly, the prodigious development of physical science within the last two centuries.

Modern civilization rests upon physical science; take away her gifts to our own country, and our position among the leading nations of the world is gone to-morrow; for it is physical science only that makes intelligence and moral energy stronger than brute force.

The whole of modern thought is steeped in science; it has made its way into the works of our best poets, and even the mere man of letters, who affects to ignore and despise science, is unconsciously impregnated with her spirit, and indebted for his best products to her methods. I believe that the greatest intellectual revolution mankind has yet seen is now slowly taking place by her agency. She is teaching the world that the ultimate court of appeal is observation and experiment, and not authority; she is teaching it to estimate the value of evidence; she is creating a firm and living faith in the existence of immutable moral and physical laws, perfect obedience to which is the highest possible aim of an intelligent being.

But of all this your old stereotyped system of education takes no note. Physical science, its methods, its problems, and its difficulties, will meet the poorest boy at every turn, and yet we educate him in such a manner that he shall enter the world as ignorant of the existence of the methods and facts of science as the day he was born. The modern world is full of artillery; and we turn out our children to do battle in it equipped with the shield and sword of an ancient gladiator.

Posterity will cry shame on us if we do not remedy this deplorable state of things. Nay, if we live twenty years longer, our own consciences will cry shame on us.

It is my firm conviction that the only way to remedy it is to make the elements of physical science an integral part of primary education. I have endeavoured to show you how that may be done for that branch of science which it is my business to pursue, and I can but add that I should look upon the day when every schoolmaster throughout this land was a centre of genuine, however rudimentary, scientific knowledge as an epoch in the history of the country.

But let me entreat you to remember my last words.

Addressing myself to you, as teachers, I would say, mere book learning in physical science is a sham and a delusion — what you teach, unless you wish to be impostors, that you must first know; and real knowledge in science means personal acquaintance with the facts, be they few or many.

VII

ON DESCARTES' "DISCOURSE TOUCHING THE METHOD OF USING ONE'S REASON RIGHTLY AND OF SEEKING SCIENTIFIC TRUTH"

It has been well said that "all the thoughts of men, from the beginning of the world until now, are linked together into one great chain"; but the conception of the intellectual filiation of mankind which is expressed in these words may, perhaps, be more fitly shadowed forth by a different metaphor. The thoughts of men seem rather to be comparable to the leaves, flowers, and fruit upon the innumerable branches of a few great stems, fed by commingled and hidden roots. These stems bear the names of the half a dozen men, endowed with intellects of heroic force and clearness, to whom we are led, at whatever point of the world of thought the attempt to trace its history commences; just as certainly as the following up the small twigs of a tree

to the branchlets which bear them, and tracing the branchlets to their supporting branches, brings us, sooner or later, to the bole.

It seems to me that the thinker who, more than any other, stands in the relation of such a stem towards the philosophy and the science of the modern world is René Descartes.° I mean that if you lay hold of any characteristic product of modern ways of thinking, either in the region of philosophy or in that of science, you find the spirit of that thought, if not its form, to have been present in the mind of the great Frenchman.

There are some men who are counted great because they represent the actuality of their own age, and mirror it as it is. Such an one was Voltaire,° of whom it was epigrammatically said, "He expressed everybody's thoughts better than anybody."° But there are other men who attain greatness because they embody the potentiality of their own day and magically reflect the future. They express the thoughts which will be everybody's two or three centuries after them. Such an one was Descartes.

Born in 1596, nearly three hundred years ago, of a noble family in Touraine, René Descartes grew up

into a sickly and diminutive child, whose keen wit soon gained him that title of "the Philosopher," which, in the mouths of his noble kinsmen, was more than half a reproach. The best schoolmasters of the day, the Jesuits,° educated him as well as a French boy of the seventeenth century could be educated. And they must have done their work honestly and well, for, before his schoolboy days were over, he had discovered that the most of what he had learned, except in mathematics, was devoid of solid and real value.

"Therefore," says he, in that "Discourse"° which I have taken for my text, "as soon as I was old enough to be set free from the government of my teachers, I entirely forsook the study of letters; and determining to seek no other knowledge than that which I could discover within myself, or in the great book of the world, I spent the remainder of my youth in travelling; in seeing courts and armies; in the society of people of different humours and conditions; in gathering varied experience; in testing myself by the chances of fortune; and in always trying to profit by my reflections on what happened. . . . And I always had an intense desire to learn how to distinguish truth from falsehood, in order to be clear about my actions, and to walk surefootedly in this life."

But "learn what is true, in order to do what is right" is the summing up of the whole duty of man,

for all who are unable to satisfy their mental hunger with the east wind of authority; and to those of us moderns who are in this position, it is one of Descartes' great claims to our reverence as a spiritual ancestor that at three-and-twenty he saw clearly that this was his duty, and acted up to his conviction. At two-and-thirty, in fact, finding all other occupations incompatible with the search after the knowledge which leads to action, and being possessed of a modest competence, he withdrew into Holland, where he spent nine years in learning and thinking, in such retirement that only one or two trusted friends knew of his whereabouts.

In 1637 the firstfruits of these long meditations were given to the world in the famous "Discourse touching the Method of using Reason rightly and of seeking Scientific Truth," which, at once an autobiography and a philosophy, clothes the deepest thought in language of exquisite harmony, simplicity, and clearness.

The central propositions of the whole "Discourse" are these. There is a path that leads to truth so surely that any one who will follow it must needs reach the goal, whether his capacity be great or small.

And there is one guiding rule by which a man may always find this path, and keep himself from straying when he has found it. This golden rule is — give unqualified assent to no propositions but those the truth of which is so clear and distinct that they cannot be doubted.

The enunciation of this great first commandment of science consecrated Doubt. It removed Doubt from the seat of penance among the grievous sins to which it had long been condemned, and enthroned it in that high place among the primary duties which is assigned to it by the scientific conscience of these latter days. Descartes was the first among the moderns to obey this commandment deliberately; and, as a matter of religious duty, to strip off all his beliefs and reduce himself to a state of intellectual nakedness, until such time as he could satisfy himself which were fit to be worn. He thought a bare skin healthier than the most respectable and well-cut clothing of what might possibly be mere shoddy.

When I say that Descartes consecrated doubt, you must remember that it was that sort of doubt which Goethe has called "the active scepticism, whose whole aim is to conquer itself" °; and not that other

sort which is born of flippancy and ignorance, and whose aim is only to perpetuate itself, as an excuse for idleness and indifference. But it is impossible to define what is meant by scientific doubt better than in Descartes' own words. After describing the gradual progress of his negative criticism, he tells us: —

> "For all that, I did not imitate the sceptics, who doubt only for doubting's sake, and pretend to be always undecided; on the contrary, my whole intention was to arrive at certainty, and to dig away the drift and the sand until I reached the rock or the clay beneath."

And further, since no man of common sense, when he pulls down his house for the purpose of rebuilding it, fails to provide himself with some shelter while the work is in progress; so, before demolishing the spacious, if not commodious, mansion of his old beliefs, Descartes thought it wise to equip himself with what he calls "*une morale par provision*,"° by which he resolved to govern his practical life until such time as he should be better instructed. The laws of this "provisional self-government" are embodied in four maxims, of which one binds our philosopher to submit himself to the laws and religion in which he was brought up; another, to act, on all

those occasions which call for action, promptly and according to the best of his judgment, and to abide, without repining, by the result; a third rule is to seek happiness in limiting his desires, rather than in attempting to satisfy them; while the last is to make the search after truth the business of his life.

Thus prepared to go on living while he doubted, Descartes proceeded to face his doubts like a man. One thing was clear to him, he would not lie to himself — would, under no penalties, say, "I am sure" of that of which he was not sure; but would go on digging and delving until he came to the solid adamant; or, at worst, made sure there was no adamant. As the record of his progress tells us, he was obliged to confess that life is full of delusions; that authority may err; that testimony may be false or mistaken; that reason lands us in endless fallacies; that memory is often as little trustworthy as hope; that the evidence of the very senses may be misunderstood; that dreams are real as long as they last, and that what we call reality may be a long and restless dream. Nay, it is conceivable that some powerful and malicious being may find his pleasure in deluding us, and in making us believe the thing which is not

every moment of our lives. What, then, is certain? What, even if such a being exists, is beyond the reach of his powers of delusion? Why, the fact that the thought, the present consciousness, exists. Our thoughts may be delusive, but they cannot be fictitious. As thoughts, they are real and existent, and the cleverest deceiver cannot make them otherwise.

Thus, thought is existence. More than that, so far as we are concerned, existence is thought, all our conceptions of existence being some kind or other of thought. Do not for a moment suppose that these are mere paradoxes or subtleties. A little reflection upon the commonest facts proves them to be irrefragable truths. For example, I take up a marble, and I find it to be a red, round, hard, single body. We call the redness, the roundness, the hardness, and the singleness "qualities" of the marble; and it sounds, at first, the height of absurdity to say that all these qualities are modes of our own consciousness, which cannot even be conceived to exist in the marble. But consider the redness, to begin with. How does the sensation of redness arise? The waves of a certain very attenuated matter, the particles of which are vibrating with vast rapidity, but with very

different velocities, strike upon the marble, and those which vibrate with one particular velocity are thrown off from its surface in all directions. The optical apparatus of the eye gathers some of these together, and gives them such a course that they impinge upon the surface of the retina, which is a singularly delicate apparatus, connected with the termination of the fibres of the optic nerve. The impulses of the attenuated matter, or ether, affect this apparatus and the fibres of the optic nerve in a certain way; and the change in the fibres of the optic nerve produces yet other changes in the brain; and these, in some fashion unknown to us, give rise to the feeling or consciousness of redness. If the marble could remain unchanged, and either the rate of vibration of the ether or the nature of the retina could be altered, the marble would seem not red, but some other colour. There are many people who are what are called colour-blind, being unable to distinguish one colour from another. Such an one might declare our marble to be green; and he would be quite as right in saying that it is green as we are in declaring it to be red. But, then, as the marble cannot in itself be both green and red at the same time, this

shows that the quality "redness" must be in our consciousness and not in the marble.

In like manner, it is easy to see that the roundness and the hardness are forms of our consciousness, belonging to the groups which we call sensations of sight and touch. If the surface of the cornea were cylindrical, we should have a very different notion of a round body from that which we possess now; and if the strength of the fabric, and the force of the muscles of the body were increased a hundred fold, our marble would seem to be as soft as a pellet of bread crumbs.

Not only is it obvious that all these qualities are in us, but, if you will make the attempt, you will find it quite impossible to conceive of "blueness," "roundness," and "hardness" as existing without reference to some such consciousness as our own. It may seem strange to say that even the "singleness" of the marble is relative to us; but extremely simple experiments will show that such is veritably the case, and that our two most trustworthy senses may be made to contradict one another on this very point. Hold the marble between the finger and thumb, and look at it in the ordinary way.

Sight and touch agree that it is single. Now squint, and sight tells you that there are two marbles, while touch asserts that there is only one. Next, return the eyes to their natural position, and having crossed the forefinger and the middle finger, put the marble between their tips. Then touch will declare that there are two marbles, while sight says that there is only one; and touch claims our belief, when we attend to it, just as imperatively as sight does.

But it may be said the marble takes up a certain space which could not be occupied at the same time by anything else. In other words, the marble has the primary quality of matter, extension. Surely this quality must be in the thing, and not in our minds. But the reply must still be, whatever may or may not, exist in the thing, all that we can know of these qualities is a state of consciousness. What we call extension is a consciousness of a relation between two or more affections, of the sense of sight or of touch. And it is wholly inconceivable that what we call extension should exist independently of such consciousness as our own. Whether, notwithstanding this inconceivability, it does so exist or not is a point on which I offer no opinion.

Thus, whatever our marble may be in itself, all that we can know of it is under the shape of a bundle of our own consciousnesses.

Nor is our knowledge of anything we know or feel, more or less than a knowledge of states of consciousness. And our whole life is made up of such states. Some of these states we refer to a cause we call "self"; others to a cause or causes which may be comprehended under the title of "not-self." But neither of the existence of "self," nor of that of "not-self," have we, or can we by any possibility have, any such unquestionable and immediate certainty as we have of the states of consciousness which we consider to be their effects. They are not immediately observed facts, but results of the application of the law of causation to those facts. Strictly speaking, the existence of a "self" and of a "not-self" are hypotheses by which we account for the facts of consciousness. They stand upon the same footing as the belief in the general trustworthiness of memory, and in the general constancy of the order of nature — as hypothetical assumptions which cannot be proved or known with that highest degree of certainty which

is given by immediate consciousness; but which, nevertheless, are of the highest practical value, inasmuch as the conclusions logically drawn from them are always verified by experience.

This, in my judgment, is the ultimate issue of Descartes' argument; but it is proper for me to point out that we have left Descartes himself some way behind us. He stopped at the famous formula, "I think, therefore I am." But a little consideration will show this formula to be full of snares and verbal entanglements. In the first place, the "therefore" has no business there. The "I am" is assumed in the "I think," which is simply another way of saying "I am thinking." And in the second place, "I think" is not one simple proposition, but three distinct assertions rolled into one. The first of these is, "something called I exists"; the second is, "something called thought exists"; and the third is, "the thought is the result of the action of the I."

Now, it will be obvious to you that the only one of these three propositions which can stand the Cartesian test of certainty is the second. It cannot be doubted, for the very doubt is an existent thought. But the first and third, whether true or not, may be

doubted, and have been doubted. For the assertor may be asked, How do you know that thought is not self-existent; or that a given thought is not the effect of its antecedent thought or of some external power? and a diversity of other questions, much more easily put than answered. Descartes, determined as he was to strip off all the garments which the intellect weaves for itself, forgot this gossamer shirt of the "self"; to the great detriment and indeed ruin of his toilet when he began to clothe himself again.

But it is beside my purpose to dwell upon the minor peculiarities of the Cartesian philosophy.° All I wish to put clearly before your minds thus far is that Descartes, having commenced by declaring doubt to be a duty, found certainty in consciousness alone; and that the necessary outcome of his views is what may properly be termed Idealism; namely, the doctrine that, whatever the universe may be, all we can know of it is the picture presented to us by consciousness. This picture may be a true likeness—though how this can be is inconceivable; or it may have no more resemblance to its cause than one of Bach's° fugues has to the person

who is playing it; or than a piece of poetry has to the mouth and lips of a reciter. It is enough for all the practical purposes of human existence if we find that our trust in the representations of consciousness is verified by results; and that, by their help, we are enabled "to walk surefootedly in this life."

Thus the method, or path, which leads to truth, indicated by Descartes, takes us straight to the Critical Idealism of his great successor Kant.° It is that idealism which declares the ultimate fact of all knowledge to be a consciousness, or, in other words, a mental phenomenon; and therefore affirms the highest of all certainties, and indeed the only absolute certainty, to be the existence of mind. But it is also that idealism which refuses to make any assertions, either positive or negative, as to what lies beyond consciousness. It accuses the subtle Berkeley° of stepping beyond the limits of knowledge when he declared that a substance of matter does not exist; and of illogicality, for not seeing that the arguments which he supposed demolished the existence of matter were equally destructive to the existence of soul. And it refuses to listen to the jargon of more recent days about

the "Absolute,"[°] and all the other hypostatized adjectives, the initial letters of the names of which are generally printed in capital letters; just as you give a Grenadier a bearskin cap to make him look more formidable than he is by nature.

I repeat, the path indicated and followed by Descartes which we have hitherto been treading leads through doubt to that critical idealism which lies at the heart of modern metaphysical thought. But the "Discourse" shows us another, and apparently very different, path, which leads, quite as definitely, to that correlation of all the phenomena of the universe with matter and motion, which lies at the heart of modern physical thought, and which most people call Materialism.

The early part of the seventeenth century, when Descartes reached manhood, is one of the great epochs of the intellectual life of mankind. At that time physical science suddenly strode into the arena of public and familiar thought, and openly challenged, not only Philosophy and the Church, but that common ignorance which passes by the name of Common Sense. The assertion of the motion of the earth was a defiance to all three, and Physical

Science threw down her glove by the hand of Galileo.°

It is not pleasant to think of the immediate result of the combat; to see the champion of science, old, worn, and on his knees before the Cardinal Inquisitor, signing his name to what he knew to be a lie. And, no doubt, the Cardinals rubbed their hands as they thought how well they had silenced and discredited their adversary. But two hundred years have passed, and however feeble or faulty her soldiers, Physical Science sits crowned and enthroned as one of the legitimate rulers of the world of thought. Charity children would be ashamed not to know that the earth moves; while the Schoolmen° are forgotten.

As a ship, which having lain becalmed with every stitch of canvas set, bounds away before the breeze which springs up astern, so the mind of Descartes, poised in equilibrium of doubt, not only yielded to the full force of the impulse towards physical science and physical ways of thought, given by his great contemporaries, Galileo and Harvey,° but shot beyond them; and anticipated, by bold speculation, the conclusions, which could only be placed upon a

secure foundation by the labours of generations of workers.

Descartes saw that the discoveries of Galileo meant that the remotest parts of the universe were governed by mechanical laws; while those of Harvey meant that the same laws presided over the operations of that portion of the world which is nearest to us, namely, our own bodily frame. And crossing the interval between the centre and its vast circumference by one of the great strides of genius, Descartes sought to resolve all the phenomena of the universe into matter and motion, or forces operating according to law.° This grand conception, which is sketched in the "Discourse," and more fully developed in the "Principes" and in the "Traité de l'Homme," he worked out with extraordinary power and knowledge; and with the effect of arriving, in the last-named essay, at that purely mechanical view of vital phenomena towards which modern physiology is striving.

Let us try to understand how Descartes got into this path, and why it led him where it did. The mechanism of the circulation of the blood had evidently taken a great hold of his mind, as he describes

it several times, at much length. After giving a full account of it in the "Discourse," and erroneously ascribing the motion of the blood, not to the contraction of the walls of the heart, but to the heat which he supposes to be generated there, he adds: —

> "This motion, which I have just explained, is as much the necessary result of the structure of the parts which one can see in the heart, and of the heat which one may feel there with one's fingers, and of the nature of the blood, which may be experimentally ascertained; as is that of a clock of the force, the situation, and the figure, of its weight and of its wheels."

But if this apparently vital operation were explicable as a simple mechanism, might not other vital operations be reducible to the same category? Descartes replies without hesitation in the affirmative.

> "The animal spirits," says he, "resemble a very subtle fluid, or a very pure and vivid flame, and are continually generated in the heart, and ascend to the brain as to a sort of reservoir. Hence they pass into the nerves and are distributed to the muscles, causing contraction, or relaxation, according to their quantity."

Thus, according to Descartes, the animal body is an automaton, which is competent to perform all

the animal functions in exactly the same way as a clock or any other piece of mechanism. As he puts the case himself: —

"In proportion as these spirits [the animal spirits] enter the cavities of the brain, they pass thence into the pores of its substance, and from these pores into the nerves; where, according as they enter, or even only tend to enter, more or less, into one than into another, they have the power of altering the figure of the muscles into which the nerves are inserted, and by this means of causing all the limbs to move. Thus, as you may have seen in the grottoes and the fountains in royal gardens, the force with which the water issues from its reservoir is sufficient to move various machines, and even to make them play instruments, or pronounce words according to the different disposition of the pipes which lead the water.

"And, in truth, the nerves of the machine which I am describing may very well be compared to the pipes of these waterworks; its muscles and its tendons to the other various engines and springs which seem to move them; its animal spirits to the water which impels them, of which the heart is the fountain; while the cavities of the brain are the central office. Moreover, respiration and other such actions as are natural and usual in the body, and which depend on the course of the spirits, are like the movements of a clock, or of a mill, which may be kept up by the ordinary flow of the water.

"The external objects which, by their mere presence, act upon the organs of the senses; and which, by this means, determine the corporal machine to move in many different ways, according as the parts of the brain are arranged, are like the strangers who, entering into some of the grottoes of these waterworks, unconsciously cause the movements which take place in their presence. For they cannot enter

without treading upon certain planks so arranged that, for example, if they approach a bathing Diana, they cause her to hide among the reeds; and if they attempt to follow her, they see approaching a Neptune, who threatens them with his trident; or if they try some other way, they cause some monster who vomits water into their faces, to dart out; or like contrivances, according to the fancy of the engineers who have made them. And lastly, when the *rational soul* is lodged in this machine, it will have its principal seat in the brain, and will take the place of the engineer, who ought to be in that part of the works with which all the pipes are connected, when he wishes to increase, or to slacken, or in some way to alter, their movements."°

And again still more strongly: —

"All the functions which I have attributed to this machine (the body), as the digestion of food, the pulsation of the heart and of the arteries; the nutrition and the growth of the limbs; respiration, wakefulness, and sleep; the reception of light, sounds, odours, flavours, heat, and such like qualities, in the organs of the external senses; the impression of the ideas of these in the organ of common sense and in the imagination; the retention, or the impression, of these ideas on the memory; the internal movements of the appetites and the passions; and lastly, the external movements of all the limbs, which follow so aptly, as well the action of the objects which are presented to the senses, as the impressions which meet in the memory, that they imitate as nearly as possible those of a real man°: I desire, I say, that you should consider that these functions in the machine naturally proceed from the mere arrangement of its organs, neither more nor less than do the movements of a clock, or other automaton, from that of its weights and its wheels; so that, so far as these are concerned, it is not necessary to conceive any other vegetative or sensitive soul, nor any other principle of motion or of life

than the blood and the spirits agitated by the fire which burns continually in the heart, and which is no wise essentially different from all the fires which exist in inanimate bodies." °

The spirit of these passages is exactly that of the most advanced physiology of the present day; all that is necessary to make them coincide with our present physiology in form is to represent the details of the working of the animal machinery in modern language, and by the aid of modern conceptions.

Most undoubtedly, the digestion of food in the human body is a purely chemical process; and the passage of the nutritive parts of that food into the blood, a physical operation. Beyond all question, the circulation of the blood is simply a matter of mechanism, and results from the structure and arrangement of the parts of the heart and vessels, from the contractility of those organs, and from the regulation of that contractility by an automatically acting nervous apparatus. The progress of physiology has further shown that the contractility of the muscles and the irritability of the nerves are purely the results of the molecular mechanism of those organs; and that the regular movements of the respiratory, alimentary, and other internal

organs are governed and guided, as mechanically, by their appropriate nervous centres. The even rhythm of the breathing of every one of us depends upon the structural integrity of a particular region of the medulla oblongata, as much as the ticking of a clock depends upon the integrity of the escapement. You may take away the hands of a clock and break up its striking machinery, but it will still tick; and a man may be unable to feel, speak, or move, and yet he will breathe.

Again, in entire accordance with Descartes' affirmation, it is certain that the modes of motion which constitute the physical basis of light, sound, and heat, are transmuted into affections of nervous matter by the sensory organs. These affections are, so to speak, a kind of physical ideas, which are retained in the central organs, constituting what might be called physical memory, and may be combined in a manner which answers to association and imagination, or may give rise to muscular contractions in those "reflex actions" which are the mechanical representatives of volition.

Consider what happens when a blow is aimed at the eye.° Instantly, and without our knowledge

or will, and even against the will, the eyelids close. What is it that happens? A picture of the rapidly advancing fist is made upon the retina at the back of the eye. The retina changes this picture into an affection of a number of the fibres of the optic nerve; the fibres of the optic nerve affect certain parts of the brain; the brain, in consequence, affects those particular fibres of the seventh nerve which go to the orbicular muscle of the eyelids; the change in these nerve-fibres causes the muscular fibres to change their dimensions, so as to become shorter and broader; and the result is the closing of the slit between the two lids, round which these fibres are disposed. Here is a pure mechanism, giving rise to a purposive action, and strictly comparable to that by which Descartes supposes his waterwork Diana to be moved. But we may go farther and inquire whether our volition, in what we term voluntary action, ever plays any other part than that of Descartes' engineer, sitting in his office, and turning this tap or the other, as he wishes to set one or another machine in motion, but exercising no direct influence upon the movements of the whole.

Our voluntary acts consist of two parts: firstly,

we desire to perform a certain action; and, secondly, we somehow set a-going a machinery which does what we desire. But so little do we directly influence that machinery, that nine-tenths of us do not even know its existence.

Suppose one wills to raise one's arm and whirl it round. Nothing is easier. But the majority of us do not know that nerves and muscles are concerned in this process; and the best anatomist among us would be amazingly perplexed if he were called upon to direct the succession, and the relative strength, of the multitudinous nerve-changes, which are the actual causes of this very simple operation.

So again in speaking. How many of us know that the voice is produced in the larynx, and modified by the mouth? How many among these instructed persons understand how the voice is produced and modified? And what living man, if he had unlimited control over all the nerves supplying the mouth and larynx of another person, could make him pronounce a sentence? Yet, if one has anything to say, what is easier than to say it? We desire the utterance of certain words: we touch the spring of the word-machine, and they are spoken.

Just as Descartes' engineer, when he wanted a particular hydraulic machine to play, had only to turn a tap, and what he wished was done. It is because the body is a machine that education is possible. Education is the formation of habits, a superinducing of an artificial organization upon the natural organization of the body; so that acts which at first required a conscious effort, eventually become unconscious and mechanical. If the act which primarily requires a distinct consciousness and volition of its details, always needed the same effort, education would be an impossibility.°

According to Descartes, then, all the functions which are common to man and animals are performed by the body as a mere mechanism, and he looks upon consciousness as the peculiar distinction of the "*chose pensante*,"° of the "rational soul," which in man (and in man only, in Descartes' opinion) is superadded to the body. This rational soul he conceived to be lodged in the pineal gland,° as in a sort of central office; and, here, by the intermediation of the animal spirits, it became aware of what was going on in the body, or influenced the operations of the body. Modern physiologists do not

ascribe so exalted a function to the little pineal gland, but, in a vague sort of way, they adopt Descartes' principle, and suppose that the soul is lodged in the cortical part of the brain — at least this is commonly regarded as the seat and instrument of consciousness.

Descartes has clearly stated what he conceived to be the difference between spirit and matter. Matter is substance which has extension, but does not think; spirit is substance which thinks, but has no extension. It is very hard to form a definite notion of what this phraseology means, when it is taken in connection with the location of the soul in the pineal gland; and I can only represent it to myself as signifying that the soul is a mathematical point, having place but not extension, within the limits of the pineal gland. Not only has it place, but it must exert force; for, according to the hypothesis, it is competent, when it wills, to change the course of the animal spirits,° which consist of matter in motion. Thus the soul becomes a centre of force. But at the same time the distinction between spirit and matter vanishes; inasmuch as matter, according to a tenable hypothesis, may be nothing but

a multitude of centres of force.° The case is worse if we adopt the modern vague notion that consciousness is seated in the gray matter of the cerebrum, generally; for, as the gray matter has extension, that which is lodged in it must also have extension. And thus we are led, in another way, to lose spirit in matter.

In truth, Descartes' physiology, like the modern physiology of which it anticipates the spirit, leads straight to materialism, so far as that title is rightly applicable to the doctrine that we have no knowledge of any thinking substance, apart from extended substance; and that thought is as much a function of matter as motion is. Thus we arrive at the singular result that, of the two paths opened up to us in the "Discourse upon Method," the one leads, by way of Berkeley and Hume,° to Kant and idealism; while the other leads, by way of De La Mettrie and Priestley,° to modern physiology and materialism.° Our stem divides into two main branches, which grow in opposite ways, and bear flowers which look as different as they can well be. But each branch is sound and healthy, and has as much life and vigour as the other.

If a botanist found this state of things in a new plant, I imagine that he might be inclined to think that his tree was monœcious — that the flowers were of different sexes, and that, so far from setting up a barrier between the two branches of the tree, the only hope of fertility lay in bringing them together. I may be taking too much of a naturalist's view of the case, but I must confess that this is exactly my notion of what is to be done with metaphysics and physics. Their differences are complementary, not antagonistic; and thought will never be completely fruitful until the one unites with the other. Let me try to explain what I mean. I hold, with the materialist, that the human body, like all living bodies, is a machine, all the operations of which will, sooner or later, be explained on physical principles. I believe that we shall, sooner or later, arrive at a mechanical equivalent of consciousness, just as we have arrived at a mechanical equivalent of heat. If a pound weight falling through a distance of a foot gives rise to a definite amount of heat, which may properly be said to be its equivalent, the same pound weight falling through a foot on a man's hand gives rise to a definite amount of

feeling, which might with equal propriety be said to be its equivalent in consciousness.° And as we already know that there is a certain parity between the intensity of a pain and the strength of one's desire to get rid of that pain; and secondly, that there is a certain correspondence between the intensity of the heat, or mechanical violence, which gives rise to the pain, and the pain itself; the possibility of the establishment of a correlation between mechanical force and volition becomes apparent. And the same conclusion is suggested by the fact that, within certain limits, the intensity of the mechanical force we exert is proportioned to the intensity of our desire to exert it.

Thus I am prepared to go with the materialists wherever the true pursuit of the path of Descartes may lead them; and I am glad, on all occasions, to declare my belief that their fearless development of the materialistic aspect of these matters has had an immense, and a most beneficial, influence upon physiology and psychology. Nay, more, when they go farther than I think they are entitled to do — when they introduce Calvinism° into science and declare that man is nothing but a ma-

chine, I do not see any particular harm in their doctrines, so long as they admit that which is a matter of experimental fact — namely, that it is a machine capable of adjusting itself within certain limits.

I protest that if some great Power would agree to make me always think what is true and do what is right, on condition of being turned into a sort of clock and wound up every morning before I got out of bed, I should instantly close with the offer.° The only freedom I care about is the freedom to do right; the freedom to do wrong I am ready to part with on the cheapest terms to any one who will take it of me. But when the materialists stray beyond the borders of their path and begin to talk about there being nothing else in the universe but matter and force and necessary laws, and all the rest of *their* "grenadiers," ° I decline to follow them. I go back to the point from which we started, and to the other path of Descartes. I remind you that we have already seen clearly and distinctly, and in a manner which admits of no doubt, that all our knowledge is a knowledge of states of consciousness. "Matter" and "Force" are, so far as we can know, mere names

for certain forms of consciousness. "Necessary" means that of which we cannot conceive the contrary. "Law" means a rule which we have always found to hold good, and which we expect always will hold good. Thus it is an indisputable truth that what we call the material world is only known to us under the forms of the ideal world; and, as Descartes tells us, our knowledge of the soul is more intimate and certain than our knowledge of the body. If I say that impenetrability is a property of matter, all that I can really mean is that the consciousness I call extension and the consciousness I call resistance constantly accompany one another. Why and how they are thus related is a mystery. And if I say that thought is a property of matter, all that I can mean is that, actually or possibly, the consciousness of extension and that of resistance accompany all other sorts of consciousness. But, as in the former case, why they are thus associated is an insoluble mystery.

From all this it follows that what I may term legitimate materialism, that is, the extension of the conceptions and of the methods of physical science to the highest as well as the lowest phenomena of

vitality, is neither more nor less than a sort of shorthand idealism; and Descartes' two paths meet at the summit of the mountain, though they set out on opposite sides of it.

The reconciliation of physics and metaphysics lies in the acknowledgment of faults upon both sides; in the confession by physics that all the phenomena of nature are, in their ultimate analysis, known to us only as facts of consciousness; in the admission by metaphysics that the facts of consciousness are practically interpretable only by the methods and the formulæ of physics: and, finally, in the observance both by metaphysical and physical thinkers of Descartes' maxim — assent to no proposition the matter of which is not so clear and distinct that it cannot be doubted.

When you did me the honour to ask me to deliver this address, I confess I was perplexed what topic to select. For you are emphatically and distinctly a *Christian* body; while science and philosophy, within the range of which lie all the topics on which I could venture to speak, are neither Christian, nor Unchristian, but are Extrachristian, and have a

world of their own, which, to use language which will be very familiar to your ears just now, is not only "unsectarian," but is altogether "secular." The arguments which I have put before you to-night, for example, are not inconsistent, so far as I know, with any form of theology.

After much consideration I thought that I might be most useful to you, if I attempted to give you some vision of this Extrachristian world, as it appears to a person who lives a good deal in it; and if I tried to show you by what methods the dwellers therein try to distinguish truth from falsehood, in regard to some of the deepest and most difficult problems that beset humanity, "in order to be clear about their actions, and to walk surefootedly in this life," as Descartes says.

It struck me that if the execution of my project came anywhere near the conception of it, you would become aware that the philosophers and the men of science are not exactly what they are sometimes represented to you to be; and that their methods and paths do not lead so perpendicularly downwards as you are occasionally told they do. And I must admit, also, that a particular and personal motive

weighed with me, — namely, the desire to show that a certain discourse,° which brought a great storm about my head some time ago, contained nothing but the ultimate development of the views of the father of modern philosophy. I do not know if I have been quite wise in allowing this last motive to weigh with me. They say that the most dangerous thing one can do in a thunderstorm is to shelter oneself under a great tree, and the history of Descartes' life shows how narrowly he escaped being riven by the lightnings, which were more destructive in his time than in ours.

Descartes lived and died a good Catholic, and prided himself upon having demonstrated the existence of God and of the soul of man. As a reward for his exertions, his old friends the Jesuits put his works upon the "Index,"° and called him an Atheist; while the Protestant divines of Holland declared him to be both a Jesuit and an Atheist. His books narrowly escaped being burned by the hangman; the fate of Vanini° was dangled before his eyes; and the misfortunes of Galileo so alarmed him that he well-nigh renounced the pursuits by which the world has so greatly benefited, and was

driven into subterfuges and evasions which were not worthy of him.

"Very cowardly," you may say; and so it was. But you must make allowance for the fact that, in the seventeenth century, not only did heresy mean possible burning, or imprisonment, but the very suspicion of it destroyed a man's peace, and rendered the calm pursuit of truth difficult or impossible. I fancy that Descartes was a man to care more about being worried and disturbed than about being burned outright; and, like many other men, sacrificed for the sake of peace and quietness what he would have stubbornly maintained against downright violence.

However this may be, let those who are sure they would have done better throw stones at him. I have no feelings but those of gratitude and reverence for the man who did what he did, when he did; and a sort of shame that any one should repine against taking a fair share of such treatment as the world thought good enough for him.°

Finally, it occurs to me that, such being my feeling about the matter, it may be useful to all of us if I ask you: "What is yours? Do you think that

the Christianity of the seventeenth century looks nobler and more attractive for such treatment of such a man?" You will hardly reply that it does. But if it does not, may it not be well if all of you do what lies within your power to prevent the Christianity of the nineteenth century from repeating the scandal?

There are one or two living men,° who, a couple of centuries hence, will be remembered as Descartes is now, because they have produced great thoughts which will live and grow as long as mankind lasts.

If the twenty-first century studies their history, it will find that the Christianity of the middle of the nineteenth century recognized them only as objects of vilification. It is for you and such as you, Christian young men, to say whether this shall be as true of the Christianity of the future as it is of that of the present. I appeal to you to say "No," in your own interest, and in that of the Christianity you profess.

In the interest of Science, no appeal is needful; as Dante° sings of Fortune —

> "Quest' è colei, ch' è tanto posta in croce
> Pur da color, che le dovrian dar lode
> Dandole biasmo a torto e mala voce.

Ma ella s' è beata, e ciò non ode:
Con l' altre prime creature lieta
Volve sua spera, e beata si gode°:"

so, whatever evil voices may rage, Science, secure among the powers that are eternal, will do her work and be blessed.

VIII

ON THE PHYSICAL BASIS OF LIFE

In order to make the title of this discourse generally intelligible, I have translated the term "Protoplasm," which is the scientific name of the substance of which I am about to speak, by the words "the physical basis of life." I suppose that, to many, the idea that there is such a thing as a physical basis, or matter, of life may be novel — so widely spread is the conception of life as a something which works through matter, but is independent of it; and even those who are aware that matter and life are inseparably connected, may not be prepared for the conclusion plainly suggested by the phrase, "*the* physical basis or matter of life," that there is some one kind of matter which is common to all living beings, and that their endless diversities are bound together by a physical, as well as an ideal,

unity. In fact, when first apprehended, such a doctrine as this appears almost shocking to common sense.

What, truly, can seem to be more obviously different from one another, in faculty, in form, and in substance, than the various kinds of living beings? What community of faculty can there be between the brightly coloured lichen, which so nearly resembles a mere mineral incrustation of the bare rock on which it grows, and the painter, to whom it is instinct with beauty, or the botanist, whom it feeds with knowledge?

Again, think of the microscopic fungus — a mere infinitesimal ovoid particle,° which finds space and duration enough to multiply into countless millions in the body of a living fly; and then of the wealth of foliage, the luxuriance of flower and fruit, which lies between this bald sketch of a plant and the giant pine of California, towering to the dimensions of a cathedral spire, or the Indian fig,° which covers acres with its profound shadow, and endures while nations and empires come and go around its vast circumference. Or, turning to the other half of the world of life, picture to yourselves the great Finner

whale, hugest of beasts that live, or have lived, disporting his eighty or ninety feet of bone, muscle, and blubber, with easy roll, among waves in which the stoutest ship that ever left dockyard would founder hopelessly; and contrast him with the invisible animalcules — mere gelatinous specks, multitudes of which could, in fact, dance upon the point of a needle with the same ease as the angels of the Schoolmen° could, in imagination. With these images before your minds, you may well ask, What community of form, or structure, is there between the animalcule and the whale; or between the fungus and the fig-tree? And, *a fortiori*, between all four?

Finally, if we regard substance, or material composition, what hidden bond can connect the flower which a girl wears in her hair and the blood which courses through her youthful veins; or, what is there in common between the dense and resisting mass of the oak, or the strong fabric of the tortoise, and those broad disks of glassy jelly which may be seen pulsating through the waters of a calm sea, but which drain away to mere films in the hand which raises them out of their element?

Such objections as these must, I think, arise in the

mind of every one who ponders, for the first time, upon the conception of a single physical basis of life underlying all the diversities of vital existence; but I propose to demonstrate to you that, notwithstanding these apparent difficulties, a threefold unity — namely, a unity of power or faculty, a unity of form, and a unity of substantial composition — does pervade the whole living world.

No very abstruse argumentation is needed, in the first place, to prove that the powers, or faculties, of all kinds of living matter, diverse as they may be in degree, are substantially similar in kind.

Goethe° has condensed a survey of all the powers of mankind into the well-known epigram: —

> "Warum treibt sich das Volk so und schreit? Es will sich ernähren,
> Kinder zeugen, und die nähren so gut es vermag.
>
> * * * * * *
>
> Weiter bringt es kein Mensch, stell' er sich wie er auch will." °

In physiological language this means that all the multifarious and complicated activities of man are comprehensible under three categories. Either they

are immediately directed towards the maintenance and development of the body, or they effect transitory changes in the relative positions of parts of the body, or they tend towards the continuance of the species. Even those manifestations of intellect, of feeling, and of will, which we rightly name the higher faculties, are not excluded from this classification, inasmuch as to every one but the subject of them, they are known only as transitory changes in the relative positions of parts of the body. Speech, gesture, and every other form of human action are, in the long run, resolvable into muscular contraction, and muscular contraction is but a transitory change in the relative positions of the parts of a muscle. But the scheme which is large enough to embrace the activities of the highest form of life, covers all those of the lower creatures. The lowest plant, or animalcule, feeds, grows, and reproduces its kind. In addition, all animals manifest those transitory changes of form which we class under irritability and contractility; and, it is more than probable, that when the vegetable world is thoroughly explored, we shall find all plants in possession of the same powers, at one time or other of their existence.

I am not now alluding to such phenomena, at once rare and conspicuous, as those exhibited by the leaflets of the sensitive plant, or the stamens of the barberry, but to much more widely spread, and, at the same time, more subtle and hidden, manifestations of vegetable contractility. You are doubtless aware that the common nettle owes its stinging property to the innumerable stiff and needle-like, though exquisitely delicate, hairs which cover its surface. Each stinging needle tapers from a broad base to a slender summit, which, though rounded at the end, is of such microscopic fineness that it readily penetrates, and breaks off in the skin. The whole hair consists of a very delicate outer case of wood, closely applied to the inner surface of which is a layer of semifluid matter, full of innumerable granules of extreme minuteness. This semifluid lining is protoplasm, which thus constitutes a kind of bag, full of a limpid liquid, and roughly corresponding in form with the interior of the hair which it fills. When viewed with a sufficiently high magnifying power, the protoplasmic layer of the nettle hair is seen to be in a condition of unceasing activity. Local contractions of the whole thickness of its sub-

stance pass slowly and gradually from point to point, and give rise to the appearance of progressive waves, just as the bending of successive stalks of corn by a breeze produces the apparent billows of a corn-field.

But, in addition to these movements, and independently of them, the granules are driven, in relatively rapid streams, through channels in the protoplasm which seem to have a considerable amount of persistence. Most commonly, the currents in adjacent parts of the protoplasm take similar directions; and, thus, there is a general stream up one side of the hair and down the other. But this does not prevent the existence of partial currents which take different routes; and, sometimes, trains of granules may be seen coursing swiftly in opposite directions, within a twenty-thousandth of an inch of one another; while, occasionally, opposite streams come into direct collision, and, after a longer or shorter struggle, one predominates. The cause of these currents seems to lie in contractions of the protoplasm which bounds the channels in which they flow, but which are so minute that the best microscopes show only their effects, and not themselves.

The spectacle afforded by the wonderful energies

prisoned within the compass of the microscopic hair of a plant, which we commonly regard as a merely passive organism, is not easily forgotten by one who has watched its display, continued hour after hour, without pause or sign of weakening. The possible complexity of many other organic forms, seemingly as simple as the protoplasm of the nettle, dawns upon one; and the comparison of such a protoplasm to a body with an internal circulation, which has been put forward by an eminent physiologist, loses much of its startling character. Currents similar to those of the hairs of the nettle have been observed in a great multitude of very different plants, and weighty authorities have suggested that they probably occur, in more or less perfection, in all young vegetable cells. If such be the case, the wonderful noonday silence of a tropical forest is, after all, due only to the dulness of our hearing; and could our ears catch the murmur of these tiny maelstroms, as they whirl in the innumerable myriads of living cells which constitute each tree, we should be stunned, as with the roar of a great city.

Among the lower plants, it is the rule rather than the exception, that contractility should be still more

openly manifested at some periods of their existence. The protoplasm of "*Algæ*"° and "*Fungi*"° becomes, under many circumstances, partially, or completely, freed from its woody case, and exhibits movements of its whole mass, or is propelled by the contractility of one, or more, hair-like prolongations of its body, which are called vibratile *cilia*. And, so far as the conditions of the manifestation of the phenomena of contractility have yet been studied, they are the same for the plant as for the animal. Heat and electric shocks influence both, and in the same way, though it may be in different degrees. It is by no means my intention to suggest that there is no difference in faculty between the lowest plant and the highest, or between plants and animals. But the difference between the powers of the lowest plant, or animal, and those of the highest, is one of degree, not of kind, and depends, as Milne-Edwards° long ago so well pointed out, upon the extent to which the principle of the division of labour is carried out in the living economy. In the lowest organism all parts are competent to perform all functions, and one and the same portion of protoplasm may successively take on the function of feeding, moving,

or reproducing apparatus. In the highest, on the contrary, a great number of parts combine to perform each function, each part doing its allotted share of the work with great accuracy and efficiency, but being useless for any other purpose.

On the other hand, notwithstanding all the fundamental resemblances which exist between the powers of the protoplasm in plants and in animals, they present a striking difference (to which I shall advert more at length presently), in the fact that plants can manufacture fresh protoplasm out of mineral compounds, whereas animals are obliged to procure it ready made, and hence, in the long run, depend upon plants. Upon what condition this difference in the powers of the two great divisions of the world of life depends, nothing is at present known.

With such qualification as arises out of the last-mentioned fact, it may be truly said that the acts of all living things are fundamentally one. Is any such unity predicable of their forms? Let us seek in easily verified facts for a reply to this question. If a drop of blood be drawn by pricking one's finger, and viewed with proper precautions and under a sufficiently high microscopic power, there will be

seen, among the innumerable multitude of little, circular, discoidal bodies, or corpuscles, which float in it and give it its colour, a comparatively small number of colourless corpuscles, of somewhat larger size and very irregular shape. If the drop of blood be kept at the temperature of the body, these colourless corpuscles will be seen to exhibit a marvellous activity, changing their forms with great rapidity, drawing in and thrusting out prolongations of their substance, and creeping about as if they were independent organisms.

The substance which is thus active is a mass of protoplasm, and its activity differs in detail, rather than in principle, from that of the protoplasm of the nettle. Under sundry circumstances the corpuscle dies and becomes distended into a round mass, in the midst of which is seen a smaller spherical body, which existed, but was more or less hidden, in the living corpuscle, and is called its *nucleus*. Corpuscles of essentially similar structure are to be found in the skin, in the lining of the mouth, and scattered through the whole framework of the body. Nay, more; in the earliest condition of the human organism, in that state in which it has but just be-

come distinguishable from the egg in which it arises, it is nothing but an aggregation of such corpuscles, and every organ of the body was, once, no more than such an aggregation.

Thus a nucleated mass of protoplasm turns out to be what may be termed the structural unit of the human body. As a matter of fact, the body, in its earliest state, is a mere multiple of such units; and, in its perfect condition, it is a multiple of such units, variously modified.

But does the formula which expresses the essential structural character of the highest animal cover all the rest, as the statement of its powers and faculties covered that of all others? Very nearly. Beast and fowl, reptile and fish, mollusk, worm, and polype, are all composed of structural units of the same character, namely, masses of protoplasm with a nucleus. There are sundry very low animals, each of which, structurally, is a mere colourless blood-corpuscle, leading an independent life. But, at the very bottom of the animal scale, even this simplicity becomes simplified, and all the phenomena of life are manifested by a particle of protoplasm without a nucleus. Nor are such organisms insignificant by reason of

their want of complexity. It is a fair question whether the protoplasm of those simplest forms of life, which people an immense extent of the bottom of the sea, would not outweigh that of all the higher living beings which inhabit the land put together. And in ancient times, no less than at the present day, such living beings as these have been the greatest of rock builders.

What has been said of the animal world is no less true of plants. Imbedded in the protoplasm at the broad, or attached, end of the nettle hair, there lies a spheroidal nucleus. Careful examination further proves that the whole substance of the nettle is made up of a repetition of such masses of nucleated protoplasm, each contained in a wooden case, which is modified in form, sometimes into a woody fibre, sometimes into a duct or spiral vessel, sometimes into a pollen grain, or an ovule. Traced back to its earliest state, the nettle arises as the man does, in a particle of nucleated protoplasm. And in the lowest plants, as in the lowest animals, a single mass of such protoplasm may constitute the whole plant, or the protoplasm may exist without a nucleus.

Under these circumstances it may well be asked, how is one mass of non-nucleated protoplasm to be distinguished from another? why call one "plant" and the other "animal"?

The only reply is that, so far as form is concerned, plants and animals are not separable, and that, in many cases, it is a mere matter of convention whether we call a given organism an animal or a plant. There is a living body called "*Æthalium septicum*," which appears upon decaying vegetable substances, and, in one of its forms, is common upon the surfaces of tan-pits. In this condition it is, to all intents and purposes, a fungus, and formerly was always regarded as such; but the remarkable investigations of De Bary have shown that, in another condition, the "*Æthalium*" is an actively locomotive creature, and takes in solid matters, upon which, apparently, it feeds, thus exhibiting the most characteristic feature of animality. Is this a plant, or is it an animal? Is it both, or is it neither? Some decide in favour of the last supposition, and establish an intermediate kingdom, a sort of biological "No Man's Land" for all these questionable forms. But, as it is admittedly impossible to draw

any distinct boundary line between this no man's land and the vegetable world on the one hand, or the animal, on the other, it appears to me that this proceeding merely doubles the difficulty which, before, was single.

Protoplasm, simple or nucleated, is the formal basis of all life. It is the clay of the potter: which, bake it and paint it as he will, remains clay, separated by artifice, and not by nature, from the commonest brick or sun-dried clod.

Thus it becomes clear that all living powers are cognate, and that all living forms are fundamentally of one character. The researches of the chemist have revealed a no less striking uniformity of material composition in living matter.

In perfect strictness, it is true that chemical investigation can tell us little or nothing, directly, of the composition of living matter, inasmuch as such matter must needs die in the act of analysis, — and upon this very obvious ground, objections, which I confess seem to me to be somewhat frivolous, have been raised to the drawing of any conclusions whatever respecting the composition of actually living matter, from that of the dead matter of life, which

alone is accessible to us. But objectors of this class do not seem to reflect that it is also, in strictness, true that we know nothing about the composition of any body whatever, as it is. The statement that a crystal of calc-spar consists of carbonate of lime is quite true, if we only mean that, by appropriate processes, it may be resolved into carbonic acid and quicklime. If you pass the same carbonic acid over the very quicklime thus obtained, you will obtain cabonate of lime again; but it will not be calc-spar, nor anything like it. Can it, therefore, be said that chemical analysis teaches nothing about the chemical composition of calc-spar? Such a statement would be absurd; but it is hardly more so than the talk one occasionally hears about the uselessness of applying the results of chemical analysis to the living bodies which have yielded them.

One fact, at any rate, is out of reach of such refinements, and this is, that all the forms of protoplasm which have yet been examined contain the four elements, carbon, hydrogen, oxygen, and nitrogen, in very complex union, and that they behave similarly towards several reagents. To this complex com-

bination, the nature of which has never been determined with exactness, the name of Protein has been applied. And if we use this term with such caution as may properly arise out of our comparative ignorance of the things for which it stands, it may be truly said, that all protoplasm is proteinaceous, or, as the white, or albumen, of an egg is one of the commonest examples of a nearly pure protein matter, we may say that all living matter is more or less albuminoid.

Perhaps it would not yet be safe to say that all forms of protoplasm are affected by the direct action of electric shocks; and yet the number of cases in which the contraction of protoplasm is shown to be effected by this agency increases every day.

Nor can it be affirmed with perfect confidence that all forms of protoplasm are liable to undergo that peculiar coagulation at a temperature of 40°–50° centigrade, which has been called "heat-stiffening," though Kühne's beautiful researches have proved this occurrence to take place in so many and such diverse living beings, that it is hardly rash to expect that the law holds good for all.

Enough has, perhaps, been said to prove the existence of a general uniformity in the character of the protoplasm, or physical basis of life, in whatever group of living beings it may be studied. But it will be understood that this general uniformity by no means excludes any amount of special modifications of the fundamental substance. The mineral, carbonate of lime, assumes an immense diversity of characters, though no one doubts that, under all these Protean changes, it is one and the same thing.

And now, what is the ultimate fate, and what the origin, of the matter of life?

Is it, as some of the older naturalists supposed, diffused throughout the universe in molecules, which are indestructible and unchangeable in themselves; but, in endless transmigration, unite in innumerable permutations, into the diversified forms of life we know?° Or, is the matter of life composed of ordinary matter, differing from it only in the manner in which its atoms are aggregated? Is it built up of ordinary matter, and again resolved into ordinary matter when its work is done?

Modern science does not hesitate a moment

between these alternatives. Physiology writes over the portals of life —

"Debemur morti nos nostraque," °

with a profounder meaning than the Roman poet attached to that melancholy line. Under whatever disguise it takes refuge, whether fungus or oak, worm or man, the living protoplasm not only ultimately dies and is resolved into its mineral and lifeless constituents, but is always dying, and, strange as the paradox may sound, could not live unless it died.

In the wonderful story of the "Peau de Chagrin," the hero becomes possessed of a magical wild ass's skin, which yields him the means of gratifying all his wishes. But its surface represents the duration of the proprietor's life; and for every satisfied desire the skin shrinks in proportion to the intensity of fruition, until at length life and the last handbreadth of the *peau de chagrin* disappear with the gratification of a last wish.

Balzac's° studies had led him over a wide range of thought and speculation, and his shadowing forth of physiological truth in this strange story may have

been intentional. At any rate, the matter of life is a veritable *peau de chagrin*, and for every vital act it is somewhat the smaller. All work implies waste, and the work of life results, directly or indirectly, in the waste of protoplasm.

Every word uttered by a speaker costs him some physical loss; and, in the strictest sense, he burns that others may have light — so much eloquence, so much of his body resolved into carbonic acid, water, and urea. It is clear that this process of expenditure cannot go on forever. But, happily, the protoplasmic *peau de chagrin* differs from Balzac's in its capacity of being repaired, and brought back to its full size, after every exertion.

For example, this present lecture, whatever its intellectual worth to you, has a certain physical value to me, which is conceivably expressible by the number of grains of protoplasm and other bodily substance wasted in maintaining my vital processes during its delivery. My *peau de chagrin* will be distinctly smaller at the end of the discourse than it was at the beginning. By and by, I shall probably have recourse to the substance commonly called mutton, for the purpose of stretching it back to its

original size. Now this mutton was once the living protoplasm, more or less modified, of another animal — a sheep. As I shall eat it, it is the same matter altered, not only by death, but by exposure to sundry artificial operations in the process of cooking.

But these changes, whatever be their extent, have not rendered it incompetent to resume its old functions as matter of life. A singular inward laboratory which I possess will dissolve a certain portion of the modified protoplasm; the solution so formed will pass into my veins; and the subtle influences to which it will then be subjected will convert the dead protoplasm into living protoplasm, and transubstantiate sheep into man.

Nor is this all. If digestion were a thing to be trifled with, I might sup upon lobster, and the matter of life of the crustacean would undergo the same wonderful metamorphosis into humanity. And were I to return to my own place by sea, and undergo shipwreck, the crustacea might, and probably would, return the compliment, and demonstrate our common nature by turning my protoplasm into living lobster. Or, if nothing better were to be had,

I might supply my wants with mere bread, and I should find the protoplasm of the wheat-plant to be convertible into man, with no more trouble than that of the sheep, and with far less, I fancy, than that of the lobster.

Hence it appears to be a matter of no great moment what animal, or what plant, I lay under contribution for protoplasm, and the fact speaks volumes for the general identity of that substance in all living beings. I share this catholicity of assimilation with other animals, all of which, so far as we know, could thrive equally well on the protoplasm of any of their fellows, or of any plant; but here the assimilative powers of the animal world cease. A solution of smelling-salts in water, with an infinitesimal proportion of some other saline matters, contains all the elementary bodies which enter into the composition of protoplasm; but, as I need hardly say, a hogshead of that fluid would not keep a hungry man from starving, nor would it save any animal whatever from a like fate. An animal cannot make protoplasm, but must take it ready-made from some other animal, or some plant — the animal's highest feat of constructive chemistry being to convert dead

protoplasm into that living matter of life which is appropriate to itself.

Therefore, in seeking for the origin of protoplasm, we must eventually turn to the vegetable world. The fluid containing carbonic acid, water, and ammonia, which offers such a Barmecide° feast to the animal, is a table richly spread to multitudes of plants; and, with a due supply of only such materials, many a plant will not only maintain itself in vigour, but grow and multiply until it has increased a million fold, or a million million fold, the quantity of protoplasm which it originally possessed; in this way building up the matter of life, to an indefinite extent, from the common matter of the universe.

Thus, the animal can only raise the complex substance of dead protoplasm to the higher power, as one may say, of living protoplasm; while the plant can raise the less complex substances — carbonic acid, water, and ammonia — to the same stage of living protoplasm, if not to the same level. But the plant also has its limitations. Some of the fungi, for example, appear to need higher compounds to start with; and no known plant can live upon the

uncompounded elements of protoplasm. A plant supplied with pure carbon, hydrogen, oxygen, and nitrogen, phosphorus, sulphur, and the like, would as infallibly die as the animal in his bath of smelling-salts, though it would be surrounded by all the constituents of protoplasm. Nor, indeed, need the process of simplification of vegetable food be carried so far as this, in order to arrive at the limit of the plant's thaumaturgy.° Let water, carbonic acid, and all the other needful constituents be supplied with ammonia, and an ordinary plant will still be unable to manufacture protoplasm.°

Thus the matter of life, so far as we know it (and we have no right to speculate on any other), breaks up, in consequence of that continual death which is the condition of its manifesting vitality, into carbonic acid, water, and ammonia, which certainly possess no properties but those of ordinary matter. And out of these same forms of ordinary matter, and from none which are simpler, the vegetable worlds builds up all the protoplasm which keeps the animal world a-going. Plants are the accumulators of the power which animals distribute and disperse.°

But it will be observed that the existence of the matter of life depends on the preëxistence of certain compounds; namely, carbonic acid, water, and ammonia. Withdraw any one of these three from the world, and all vital phenomena come to an end. They are related to the protoplasm of the plant, as the protoplasm of the plant is to that of the animal. Carbon, hydrogen, oxygen, and nitrogen are all lifeless bodies. Of these, carbon and oxgyen unite in certain proportions and under certain conditions to give rise to carbonic acid; hydrogen and oxygen produce water; nitrogen and hydrogen give rise to ammonia. These new compounds, like the elementary bodies of which they are composed, are lifeless. But when they are brought together, under certain conditions they give rise to the still more complex body, protoplasm, and this protoplasm exhibits the phenomena of life.

I see no break in this series of steps in molecular complication, and I am unable to understand why the language which is applicable to any one term of the series may not be used with any of the others. We think fit to call different kinds of matter carbon, oxygen, hydrogen, and nitrogen, and to speak of the

various powers and activities of these substances as the properties of the matter of which they are composed.

When hydrogen and oxygen are mixed in a certain proportion, and an electric spark is passed through them, they disappear, and a quantity of water, equal in weight to the sum of their weights, appears in their place. There is not the slightest parity between the passive and active powers of the water, and those of the oxygen and hydrogen which have given rise to it. At 32° Fahrenheit, and far below that temperature, oxygen and hydrogen are elastic gaseous bodies, whose particles tend to rush away from one another with great force. Water, at the same temperature, is a strong though brittle solid, whose particles tend to cohere into definite geometrical shapes, and sometimes build up frosty imitations of the most complex forms of vegetable foliage.

Nevertheless we call these, and many other strange phenomena, the properties of the water, and we do not hesitate to believe that, in some way or another, they result from the properties of the component elements of the water. We do not assume that a

something called "aquosity" entered into and took possession of the oxide of hydrogen as soon as it was formed, and then guided the aqueous particles to their places in the facets of the crystal, or amongst the leaflets of the hoar-frost. On the contrary, we live in the hope and in the faith that, by the advance of molecular physics, we shall by and by be able to see our way as clearly from the constituents of water to the properties of water, as we are now able to deduce the operations of a watch from the form of its parts and the manner in which they are put together.

Is the case in any way changed when carbonic acid, water, and ammonia disappear, and in their place, under the influence of preëxisting living protoplasm, an equivalent weight of the matter of life makes its appearance?

It is true that there is no sort of parity between the properties of the components and the properties of the resultant, but neither was there in the case of the water. It is also true that what I have spoken of as the influence of preëxisting living matter is something quite unintelligible; but does anybody quite comprehend the *modus operandi* of an

electric spark, which traverses a mixture of oxygen and hydrogen?

What justification is there, then, for the assumption of the existence in the living matter of a something which has no representative, or correlative, in the not living matter which gave rise to it? What better philosophical status has "vitality" than "aquosity"? And why should "vitality" hope for a better fate than the other "itys" which have disappeared since Martinus Scriblerus° accounted for the operation of the meat-jack by its inherent "meat-roasting quality," and scorned the "materialism" of those who explained the turning of the spit by a certain mechanism worked by the draught of the chimney?

If scientific language is to possess a definite and constant signification whenever it is employed, it seems to me that we are logically bound to apply to the protoplasm, or physical basis of life, the same conceptions as those which are held to be legitimate elsewhere. If the phenomena exhibited by water are its properties, so are those presented by protoplasm, living or dead, its properties.

If the properties of water may be properly said to

result from the nature and disposition of its component molecules, I can find no intelligible ground for refusing to say that the properties of protoplasm result from the nature and disposition of its molecules.

But I bid you beware that, in accepting these conclusions, you are placing your feet on the first rung of a ladder which, in most people's estimation, is the reverse of Jacob's,° and leads to the antipodes of heaven. It may seem a small thing to admit that the dull vital actions of a fungus, or a foraminifer, are the properties of their protoplasm, and are the direct results of the nature of the matter of which they are composed. But if, as I have endeavoured to prove to you, their protoplasm is essentially identical with, and most readily converted into, that of any animal, I can discover no logical halting-place between the admission that such is the case, and the further concession that all vital action may, with equal propriety, be said to be the result of the molecular forces of the protoplasm which displays it. And if so, it must be true, in the same sense and to the same extent that the thoughts to which I am now giving utterance, and your thoughts regarding

them, are the expression of molecular changes in that matter of life which is the source of our other vital phenomena.

Past experience leads me to be tolerably certain that, when the propositions I have just placed before you are accessible to public comment and criticism, they will be condemned by many zealous persons, and perhaps by some few of the wise and thoughtful. I should not wonder if "gross and brutal materialism" were the mildest phrase applied to them in certain quarters. And, most undoubtedly, the terms of the propositions are distinctly materialistic. Nevertheless two things are certain: the one, that I hold the statements to be substantially true; the other, that I, individually, am no materialist, but, on the contrary, believe materialism to involve grave philosophical error.

This union of materialistic terminology with the repudiation of materialistic philosophy I share with some of the most thoughtful men with whom I am acquainted. And, when I first undertook to deliver the present discourse, it appeared to me to be a fitting opportunity to explain how such a union is

not only consistent with, but necessitated by, sound logic. I purposed to lead you through the territory of vital phenomena to the materialistic slough in which you find yourselves now plunged, and then to point out to you the sole path by which, in my judgment, extrication is possible.

Let us suppose that knowledge is absolute,° and not relative, and therefore, that our conception of matter represents that which it really is. Let us suppose, further, that we do know more of cause and effect than a certain definite order of succession among facts, and that we have a knowledge of the necessity of that succession — and hence, of necessary laws — and I, for my part, do not see what escape there is from utter materialism and necessarianism. For it is obvious that our knowledge of what we call the material world is, to begin with, at least as certain and definite as that of the spiritual world, and that our acquaintance with law is of as old a date as our knowledge of spontaneity. Further, I take it to be demonstrable that it is utterly impossible to prove that anything whatever may not be the effect of a material and necessary cause, and that human logic is equally incompetent to

prove that any act is really spontaneous. A really spontaneous act is one which, by the assumption, has no cause; and the attempt to prove such a negative as this is, on the face of the matter, absurd. And while it is thus a philosophical impossibility to demonstrate that any given phenomenon is not the effect of a material cause, any one who is acquainted with the history of science will admit, that its progress has, in all ages, meant, and now, more than ever, means, the extension of the province of what we call matter and causation, and the concomitant gradual banishment from all regions of human thought of what we call spirit and spontaneity.

I have endeavoured, in the first part of this discourse, to give you a conception of the direction towards which modern physiology is tending; and I ask you, what is the difference between the conception of life as the product of a certain disposition of material molecules, and the old notion of an Archæus° governing and directing blind matter within each living body, except this — that here, as elsewhere, matter and law have devoured spirit and spontaneity? And as surely as every future

grows out of past and present, so will the physiology of the future gradually extend the realm of matter and law until it is coextensive with knowledge, with feeling, and with action.

The consciousness of this great truth weighs like a nightmare, I believe, upon many of the best minds of these days. They watch what they conceive to be the progress of materialism, in such fear and powerless anger as a savage feels, when, during an eclipse, the great shadow creeps over the face of the sun. The advancing tide of matter threatens to drown their souls; the tightening grasp of law impedes their freedom; they are alarmed lest man's moral nature be debased by the increase of his wisdom.

If the "New Philosophy"° be worthy of the reprobation with which it is visited, I confess their fears seem to me to be well founded. While, on the contrary, could David Hume be consulted, I think he would smile at their perplexities, and chide them for doing even as the heathen, and falling down in terror before the hideous idols their own hands have raised.

For, after all, what do we know of this terrible

"matter," except as a name for the unknown and hypothetical cause of states of our own consciousness? And what do we know of that "spirit" over whose threatened extinction by matter a great lamentation is arising, like that which was heard at the death of Pan,° except that it is also a name for an unknown and hypothetical cause, or condition, of states of consciousness? In other words, matter and spirit are but names for the imaginary substrata of groups of natural phenomena.

And what is the dire necessity and "iron" law under which men groan? Truly, most gratuitously invented bugbears. I suppose if there be an "iron" law, it is that of gravitation; and if there be a physical necessity, it is that a stone, unsupported, must fall to the ground. But what is all we really know, and can know, about the latter phenomenon? Simply, that, in all human experience, stones have fallen to the ground under these conditions; that we have not the smallest reason for believing that any stone so circumstanced will not fall to the ground; and that we have, on the contrary, every reason to believe that it will so fall. It is very convenient to indicate that all the conditions of belief

have been fulfilled in this case, by calling the statement that unsupported stones will fall to the ground, "a law of nature." But when, as commonly happens, we change *will* into *must*, we introduce an idea of necessity which most assuredly does not lie in the observed facts, and has no warranty that I can discover elsewhere. For my part, I utterly repudiate and anathematize the intruder. Fact I know, and Law I know, but what is this Necessity, save an empty shadow of my own mind's throwing?

But, if it is certain that we can have no knowledge of the nature of either matter or spirit, and that the notion of necessity is something illegitimately thrust into the perfectly legitimate conception of law, the materialistic position that there is nothing in the world but matter, force, and necessity, is as utterly devoid of justification as the most baseless of theological dogmas. The fundamental doctrines of materialism, like those of spiritualism, and most other "isms," lie outside "the limits of philosophical inquiry," and David Hume's great service to humanity is his irrefragable demonstration of what these limits are. Hume called himself a sceptic, and therefore others cannot be blamed if they apply the

same title to him; but that does not alter the fact that the name, with its existing implications, does him gross injustice.

If a man asks me what the politics of the inhabitants of the moon are, and I reply that I do not know; that neither I, nor any one else, have any means of knowing; and that, under these circumstances, I decline to trouble myself about the subject at all, I do not think he has any right to call me a sceptic. On the contrary, in replying thus, I conceive that I am simply honest and truthful, and show a proper regard for the economy of time. So Hume's strong and subtle intellect takes up a great many problems about which we are naturally curious, and shows us that they are essentially questions of lunar politics, in their essence incapable of being answered, and therefore not worth the attention of men who have work to do in the world. And he thus ends one of his essays: —

"If we take in hand any volume of Divinity, or school metaphysics, for instance, let us ask, *Does it contain any abstract reasoning concerning quantity or number?* No. *Does it contain any experimental reasoning concerning matter of fact and existence?* No. Commit it then to the flames; for it can contain nothing but sophistry and illusion." °

Permit me to enforce this most wise advice. Why trouble ourselves about matters of which, however important they may be, we do know nothing, and can know nothing? We live in a world which is full of misery and ignorance, and the plain duty of each and all of us is to try to make the little corner he can influence somewhat less miserable and somewhat less ignorant than it was before he entered it. To do this effectually it is necessary to be fully possessed of only two beliefs: the first, that the order of nature is ascertainable by our faculties to an extent which is practically unlimited; the second, that our volition counts for something as a condition of the course of events.

Each of these beliefs can be verified experimentally, as often as we like to try. Each, therefore, stands upon the strongest foundation upon which any belief can rest, and forms one of our highest truths. If we find that the ascertainment of the order of nature is facilitated by using one terminology, or one set of symbols, rather than another, it is our clear duty to use the former; and no harm can accrue, so long as we bear in mind that we are dealing merely with terms and symbols.

In itself it is of little moment whether we express the phenomena of matter in terms of spirit, or the phenomena of spirit in terms of matter: matter may be regarded as a form of thought, thought may be regarded as a property of matter — each statement has a certain relative truth. But with a view to the progress of science, the materialistic terminology is in every way to be preferred. For it connects thought with the other phenomena of the universe, and suggests inquiry into the nature of those physical conditions, or concomitants of thought, which are more or less accessible to us, and a knowledge of which may, in future, help us to exercise the same kind of control over the world of thought, as we already possess in respect of the material world; whereas, the alternative, or spiritualistic, terminology is utterly barren, and leads to nothing but obscurity and confusion of ideas.

Thus there can be little doubt that the further science advances, the more extensively and consistently will all the phenomena of nature be represented by materialistic formulæ and symbols.

But the man of science, who, forgetting the limits of philosophical inquiry, slides from these formulæ

and symbols into what is commonly understood by materialism, seems to me to place himself on a level with the mathematician, who should mistake the x's and y's with which he works his problems, for real entities — and with this further disadvantage, as compared with the mathematician, that the blunders of the latter are of no practical consequence, while the errors of systematic materialism may paralyze the energies and destroy the beauty of a life.

NOTES

AUTOBIOGRAPHY

The immediate cause of this autobiography is given in a letter Huxley wrote to his wife, March 2, 1889. "A man who is bringing out a series of portraits of celebrities, with a sketch of their career attached, has bothered me out of my life for something to go with my portrait, and to escape the abominable bad taste of some of the notices, I have done that. I shall show it you before it goes back to Engel in proof."

This sketch is found in his *Collected Essays*, Vol. I, 1–17. It is scarcely an autobiography in the true sense of the word, for it tells but little of a life filled with scientific activity and association with the highest intellects of his age. For a fuller account of his life, read *Life and Letters of Thomas H. Huxley*, by his son, Leonard Huxley.

1 : vi. **Butler,** Joseph, Bishop of Durham (1692–1738). An English clergyman and theologian. Two years before his death he wrote the famous *Analogy of Religion, Natural and Revealed, to the Constitution and Course of Nature.* This *Analogy* is still read as one of the strongest books of Christian apologetics, or defence of the Christian faith. It was a book with which Huxley was familiar, and is frequently mentioned in his letters.

1 : 3. **Auckland.** The palace of the Bishop of Durham, ten miles south of Durham.

2 : 4. **Boswellian.** James Boswell (1740–1795), the biographer of the great Dr. Samuel Johnson, who, on account of the minuteness of his biography, has had his name come to be synonymous with officious and prying curiosity into a person's private life and thoughts.

2 : 10. **Bene qui latuit, bene vixit.** He lives well, who lives in seclusion.

3 : 7. **Hyde Park Corner.** The northeastern corner of Hyde Park, not far from the fashionable part of the city of London.

4 : 12. **Apostle.** The Apostle Thomas, who doubted the fact of Christ's resurrection. Huxley's attitude of demanding scientific verification finds something congenial in the doubting Apostle.

4 : 19. **Faculty for drawing.** This faculty stood him in good stead in his scientific studies. He used it freely for humorous purposes in his letters, frequently illustrating them with ludicrous sketches which remind us of the illustrations by Thackeray in some of his novels.

6 : 12. **Herbert Spencer** (1820–1903). An English philosopher and sociologist. He was a close friend of Huxley.

7 : 20. **Sydney**, in Australia. A place visited by Huxley on his Rattlesnake expedition, for which see later.

8 : 11. **In partibus infidelium.** Among the unbelievers Huxley is humorously referring to the charges frequently brought against him that he, on account of his scientific view of the world, was to be classed among the atheists

and infidels who regard the universe as but a mechanical organization of dead laws.

10 : 3. **"Sweet south upon a bed of violets."** Cf. *Twelfth Night*, Act I, Scene I, 5.

10 : 6. **Hypochondriacal dyspepsia**. Dyspepsia accompanied by mental depression.

10 : 8. **Lehrjahre**. Apprenticeship. Years of schooling.

10 : 23. **Mr. Wharton Jones**. Huxley never forgot his debt to him, and years after helped to obtain for him a pension.

11 : 6. **I worked hard to obtain his approbation.** The following lines from his *Life and Letters* throws an interesting light on his life at this time: "I have a story from one of them that when the other students used to go out into the court of the hospital after lectures were over, they would invariably catch sight of young Huxley's dark head at a certain window bent over a microscope while they amused themselves outside. The constant silhouette framed in the outlines of the window tickled the fancy of the young fellows, and a wag amongst them dubbed it with a name that stuck, 'The Sign of the Head and Microscope.'" Vol. I, p. 22.

The scientific paper, too, which he mentions, was somewhat remarkable under the circumstances. It is not given to every medical student to make an anatomical discovery, even a small one. In this case the boy of nineteen, investigating things for himself, found a hitherto undiscovered membrane in the root of the human hair, which received the name of Huxley's layer.

12 : 10. **Somerset House.** A palace on the Strand, London, built by the Protector Somerset, 1549. It has been rebuilt since 1775, and is now used for government offices.

13 : 2. **Nelson**, Horatio (1758–1805). The famous English admiral who enabled England to thwart Napoleon's plan of conquering England and the rest of Europe at the Battle of Trafalgar.

13 : 3. **Victory.** The flagship of Admiral Lord Nelson at the great battle of Trafalgar, 1805. It was long afterwards kept at Southampton as a receiving ship for the navy. To-day it is kept as a relic of its famous commander and his famous victory over the French.

13 : 6. **Sir John Richardson** (1787–1865). It was fortunate that Huxley in his student days became associated with such indefatigable naturalists and scientists as Richardson and Jones. They gave him his true bent.

16 : 9. **Buffon.** Comte de Georges Louis Leclerc (1707–1788), a famous French naturalist. — **Suites à Buffon.** Sequels to Buffon.

16 : 11. **Four years of our absence.** Interesting accounts of this journey are preserved in his letters, and from an article "Science at Sea," which appeared in the *Westminster Review*, January, 1854. The following is from the latter: —

Any adventures ashore were mere oases, separated by whole deserts of the most wearisome ennui. For weeks, perhaps, those who were not fortunate enough to be living hard and getting fatigued every day in the boats were yawning away their existence in an atmosphere only comparable

to that of an orchid house, a life in view of which that of Mariana in the moated grange has its attractions. For instance, consider this extract from the journal of one of the officers, date, August, 1849: —

"Rain! rain! *encore et toujours* — I wonder if it is possible for the mind of man to conceive anything more degradingly offensive than the condition of us 150 men, shut up in this wooden box, and being watered with hot water as we are now. It is no exaggeration to say hot, for the temperature is that at which people at home commonly take a hot bath. It rains so hard that we have caught seven tons of water in one day, and it is therefore impossible to go on deck, though, if one did, one's condition would not be much improved. A hot Scotch mist covers the sea and hides the land, so that no surveying can be done; moving about in the slightest degree causes a flood of perspiration to pour out; all energy is completely gone, and if I could help it I would not think, even; it's too hot. The rain awnings are spread, and we can have no wind sails up; if we could, there is not a breath of wind to fill them; and consequently, the lower and main decks are utterly unventilated: a sort of solution of man in steam fills them from end to end, and surrounds the lights with a lurid halo. It's too hot to sleep, and my sole amusement consists in watching the cockroaches, which are in a state of intense excitement and happiness. They manifest these feelings in a very remarkable manner — a sudden unanimous impulse seems to seize the obscene thousands which usually lurk

hidden in the corners of my cabin. Out they rush, helter-skelter, and run over me, my table, and my desk; others more vigorous, fly, quite regardless of consequences, until they hit against something, upon which, half spreading their wings, they make their heads a pivot and spin round in a circle, in a manner which indicates a temporary aberration of the cockroach mind. It is these outbreaks alone which rouse us from our lassitude. Knocks are heard resounding on all sides, and each inhabitant in the cabin, armed with a slipper, is seen taking ample revenge upon the disturbers of the rest and the destroyers of his body and clothes."

Here, on the other hand, is an oasis, a bartering scene at Bruny Island, in the Louisade:—

"We landed at the same place as before, and this time the natives ran down prancing and gesticulating. Many of them had garlands of green leaves round their heads, knees, and ankles; some of them wore long streamers depending from their arms and ears and floating in the wind as they galloped along, shaking their spears and prancing just as boys do when they play at horses. They soon surrounded us, shouting, 'Kelumai! Kelumai!' (their word for iron), and offering us all sorts of things in exchange. One very fine athletic man, 'Kai-oo-why-who-at' by name, was perfectly mad to get an axe, and very soon comprehended the arrangements that were made. Mr. Brady drew ten lines on the sand and laid an axe down by them, giving K—— (I really can't write that long name all over again) to under-

stand by signs that when there was a 'bahar' (yam) on every mark he should have the axe. He comprehended directly, and bolted off as fast as he could run, soon returning with his hands full of yams, which he deposited one by one on the appropriate lines; then, fearful lest some of the others should do him out of the axe, he caught hold of Brady by the arm, and would not let him go until yams enough had been brought by the others to make up the number, and the axe was handed over to him.

"Then was there a yell of delight! He jumped up with the axe, flourished it, passed it to his companions, tumbled down and rolled over, kicking up his heels in the air, and finally, catching hold of me, we had a grand waltz, with various poses plastiques, for about a quarter of a mile. I daresay he was unsophisticated enough to imagine that I was filled with sympathetic joy, but I grieve to say that I was taking care all the while to direct his steps towards the village, which, as we had as yet examined none of their houses, I was most desirous of entering under my friend's sanction. I think he suspected something, for he looked at me rather dubiously when I directed our steps towards the entrance in the bush which led to the houses, and wanted me to come back, but I was urgent, so he gave way, and we both entered the open space, where we were joined by two or three others, and sat down under a cocoanut tree.

"I persuaded him to sit for his portrait (taking care first that my back was against the tree and my pistols handy), and we ate green cocoanuts together, at last attaining to so great a pitch of intimacy that he made me change

names with him, calling himself 'Tamoo' (my Cape York name), and giving me to understand that I was to take his own lengthy appellation. When I did so, and talked to him as 'Tamoo,' nothing could exceed the delight of all around; they patted me as you would a child, and evidently said to one another, 'This really seems to be a very intelligent white fellow.'"

16 : 13. **Linnean Society.** An English Botanical Society named after the famous Swedish botanist, Carolus Linnæus (1707–1778). Huxley was admitted to this society in 1858.

16 : 18. **Royal Society.** The Royal Society of London for improving Natural Knowledge. For an account of its founding, see the lecture "On Improving Natural Knowledge." Huxley was admitted to membership in 1851.

17 : 3. **When I hear . . . education.** It was several years after his return to London before Huxley could hope to make even a decent livelihood by science. In 1851, he writes:—

"The difficulties of obtaining a decent position in England in anything like a reasonable time seem to me greater then ever they were. To attempt to live by any scientific pursuit is a farce. Nothing but what is absolutely practical will go down in England. A man of science may earn great distinction, but not bread. He will get invitations to all sorts of dinners and conversaziones, but not enough income to pay his cab fare. A man of science in these times is like an Esau who sells his birthright for a mess of pottage. Again, if one turns to practice, it is still the old story —

wait; and only after years of working like a galley-slave and intriguing like a courtier is there any chance of getting a decent livelihood. I am not at all sure if . . . it would not be the most prudent thing to stick by the Service: there at any rate is certainty in health and in sickness." — *Life and Letters*, Vol. I.

17 : 14. **Père Goriot.** A novel by the French novelist, Balzac. The plot reminds us of *King Lear*.

17 : 15. **À nous deux.** Equivalent to our phrase, we two for each other; or, there is to be war between us.

17 : 18. **Professor Tyndall.** John Tyndall (1820–1893), the prominent physicist, a friend of Huxley.

18 : 4. **Edward Forbes.** He died in 1853. He had assisted Huxley in many ways, but chiefly through the warm interest in his work. He was one of the first to see that Huxley was destined to be one of the leaders in science. In 1851 Huxley wrote of him: "He is one of the few men I have ever met to whom I can feel obliged, without losing a particle of independence or self-respect."

18 : 7. **Paleontologist.** Lecturer on ancient life as found in fossils.

18 : 15. **Disliked public speaking.** Huxley never completely got away from this early dislike. The following is an account of his first attempt:—

"On the first day there was a dearth of matter in our section. People had not arrived with their papers. So by way of finding out whether I could speak in public or not, I got up and talked to them for about twenty minutes. I

was considerably surprised to find that when once I had made the plunge, my tongue went glibly enough."

18 : 21. First important audience . . . 1852. An account of this is preserved in his own words: "It was the first lecture I had ever given in my life, and to what is considered the best audience in London. As nothing ever works up my energies but a high flight, I had chosen a very difficult abstract point, in my view of which I stand almost alone. When I took a glimpse into the theatre and saw it full of faces, I did feel most amazingly uncomfortable. I can now quite understand what it is to be going to be hanged, and nothing but the necessity of the case prevented me from running away.

"However, when the hour struck, in I marched, and began to deliver my discourse. For ten minutes I did not know quite where I was, but by degrees I got used to it, and gradually gained perfect command of myself and of my subject. I believe I contrived to interest my audience, and upon the whole I think I may say that this essay was successful." —*Life and Letters,* Vol. I, p. 106.

18 : 23. Malgré moi. In spite of myself.

19 : 5. Royal Institution. This was founded as a means by which leading men of science might give accounts of their work to London society.

20 : 8. Ambition for scientific fame. In 1850, when but a young man of twenty-five, he wrote to his sister: "There are many nice people in this world for whose praise or blame I care not a whistle. I don't know and I don't care

whether I shall ever be what is called a great man. I will leave my mark somewhere, and it shall be clear and distinct T. H. H., his mark and free from the abominable blur of cant, humbug, and self-seeking which surrounds everything in this present world — that is to say, supposing that I am not already unconsciously tainted myself, a result of which I have a morbid dread. I am perhaps overrating myself. You must put me in mind of my better self, as you did in your last letter, when you write." — *Life and Letters*, Vol. I, p. 69.

20 : 10. **Popularization of science.** As an illustration of this, see the lecture on "A Piece of Chalk" in this volume. See also a similar lecture on "A Piece of Coal" in his *Collected Essays*. His lectures to workingmen were also directed to this end. Read the following extract from a letter: "I want the working classes to understand that Science and her ways are great facts for them — that physical virtue is the base of all other, and that they are to be clean and temperate and all the rest — not because fellows in black with white ties tell them so, but because these are plain and patent laws of nature which they must obey 'under penalties.' I am sick of the dilettante middle class, and mean to try what I can do with these hard-handed fellows who live among facts." — *Life and Letters*, Vol. I, p. 149.

Lord Kelvin, in presenting Huxley with the Darwin Medal, used these words: "To the world at large, perhaps, Mr. Huxley's share in moulding the thesis of Natural Selection is less well known than is his bold, unwearied exposition and

defence of it after it had been made public. And, indeed, a speculative trifler, revelling in the problems of the 'might have been,' would find a congenial theme in the inquiry how soon what we now call 'Darwinism' would have met with the acceptance with which it has met, and gained the power which it has gained, had it not been for the brilliant advocacy with which in its early days it was expounded to all classes of men.

"That advocacy had one striking mark: while it made or strove to make clear how deep the new view went down, and how far it reached, it never shrank from trying to make equally clear the limit beyond which it could not go." — *Life and Letters*, Vol. I, p. 224.

20 : 11. **Scientific education.** For his idea of the importance of this, see his lecture "On a Liberal Education" in this volume, and the notes which give extracts from his writings.

20 : 12. **Skirmishes over evolution.** In 1859, Darwin published his *Origin of Species.* Huxley at once hailed it with approbation and became general agent of the Darwinian hypothesis.

"As I have already said, I imagine that most of those of my contemporaries who thought seriously about the matter, were very much in my own state of mind — inclined to say to both Mosaists and Evolutionists, 'a plague on both your houses!' and disposed to turn aside from an interminable and apparently fruitless discussion to labour in the fertile fields of ascertainable fact. And I may therefore suppose

that the publication of the Darwin and Wallace paper in 1858, and still more that of the *Origin* in 1859, had the effect upon them of the flash of light which, to a man who has lost himself on a dark night, suddenly reveals a road which, whether it takes him straight home or not, certainly goes his way. That which we were looking for, and could not find, was a hypothesis respecting the origin of known organic forms which assumed the operation of no causes but such as could be proved to be actually at work. We wanted, not to pin our faith to that or any other speculation, but to get hold of clear and definite conceptions which could be brought face to face with facts and have their validity tested. The *Origin* provided us with the working hypothesis we sought. Moreover, it did the immense service of freeing us forever from the dilemma — Refuse to accept the creation hypothesis, and what have you to propose that can be accepted by any cautious reasoner? In 1857 I had no answer ready, and I do not think that anyone else had. A year later we reproached ourselves with dulness for being perplexed with such an inquiry. My reflection, when I first made myself master of the central idea of the *Origin* was, 'How extremely stupid not to have thought of that!' I suppose that Columbus' companions said much the same when he made the egg stand on end. The facts of variability, of the struggle for existence, of adaptation to conditions, were notorious enough; but none of us had suspected that the road to the heart of the species problem lay through them, until Darwin and Wallace dispelled the darkness, and the beacon-fire of the *Origin* guided the benighted." —

Life and Letters of Charles Darwin, from a chapter contributed by Huxley.

He also wrote later: "As for me, in part from force of circumstances and in part from a conviction I could be of most use in that way, I have played the part of something between maid-of-all-work and gladiator-general for science, and deserve no such prominence as your kindness has assigned to me." — *Life and Letters*, Vol. II, p. 173.

20 : 24. **Presidency of the Royal Society**. He was elected to this office in 1883, but was forced to resign before his term was over on account of ill health. He writes of this in 1888. "The Royal Society has dealt very kindly with me. They patted me on the back thirty-seven years ago, and it was a great encouragement. They give me their best, now that my race is run, and it is a great consolation."

21 : 9. **New Reformation.** Mrs. Humphry Ward gave this title to the scientific movement of the nineteenth century. Huxley was one of those most concerned in its spread. He writes in 1889: "I find people are watching the game with great interest, and if it should be possible for me to give a little shove to the 'New Reformation,' I shall think the fag end of my life well spent.

"After all, the reproach made to the English people 'that they care for nothing but religion and politics' is rather to their credit. In the long run these are the two things that ought to interest a man more than any others." — *Life and Letters*, Vol. II, p. 237.

And in 1873 he writes to his wife: "But to say truth, I am not greatly concerned about any reputation except that

of being entirely honest and straightforward, and that reputation I think and hope I have.

"For the rest — the part I have to play is not to found a new school of thought or to reconcile the antagonisms of the old schools. We are in the midst of a gigantic movement greater than that which preceded and produced the Reformation, and really only the continuation of that movement." — *Life and Letters,* Vol. I, p. 427.

ON THE ADVISABLENESS OF IMPROVING NATURAL KNOWLEDGE

A lay sermon delivered in St. Martin's Hall [London] on the evening of Sunday, the 7th of January, 1866, and subsequently published in the *Fortnightly Review.*

22 : 9. **Plague**. An epidemic of high mortality. The disease known specifically as the plague, or Bubonic Plague, entered Europe from the Levant in the sixth century, and lingered in scattered localities for over a thousand years. The Black Death that swept over Europe was a modified form of this plague. It still lingers in some portions of Asia, as in India and China.

23 : 2. **Defoe**, Daniel (1659–1731), one of the first English novelists and political writers. He is chiefly known to us as the author of *Robinson Crusoe,* regarded by some as the first English novel.

24 : 2. **City within the walls**. London at this time was surrounded by a wall which extended from the Temple on the west to a point nearly a mile north of the river, and east

to the Tower. This was, until near the beginning of the last century, the chief residence and business district of the city.

24 : 9. **Republicans**. The old Puritan party of Cromwell and Milton — the party that wished to abolish the monarchy and substitute a republican commonwealth.

24 : 10. **Papists**. The English at this time, and indeed for some time after, were exceedingly fearful of the Catholics, who were thought to desire the return of England to the ancient faith. Charles II and his brother James II were both Catholics. It was for the reason of their being opposed to the existing state of affairs that at that time harsh laws were passed against both the Catholics and the Puritans. No offices in the state were opened to them.

25 : 7. **Rochester**. John Wilmot, Earl of Rochester (1647–1680). A courtier and poet of the reign of Charles II. — **Sedley**, Sir Charles (1639–1701), a wit, poet, dramatist of the Restoration. His life was, even for that time, scandalous; and the wickedness of the court during the time immediately following the Restoration is notorious.

25 : 12. **Laud**, William (1575–1645). He was the famous bishop of London and Archbishop of Canterbury of the reign of Charles I, who attempted with Charles's help to suppress all the nonconforming Puritans to the church and the king. He was beheaded in 1645. — **Milton**, John (1608–1674). The great English poet, author of the *Paradise Lost* and other poems well known to all students of English literature. He was the unbending champion of Puritanism, and during the Commonwealth was Latin Secretary to Cromwell, a position which would now be equivalent to Secretary of State.

26 : 8. **Astronomy**. The science of astronomy received a great impetus from the discoveries of Copernicus and Galileo. Copernicus (1473–1543) proved that the sun, not the earth, was the centre of the solar system. Galileo, with his invention of the telescope, made possible many future discoveries. He discovered sun spots and the moons of Jupiter.

26 : 14. **Copernican hypothesis**. See above.

26 : 23. **Torricelli**, Evangelista (1608–1647). A celebrated Italian physicist and mathematician. He was the friend and amanuensis of Galileo. He discovered the principles of the barometer, the experiment referred to.

27 : 6. **Galileo** (1564–1642). A famous Italian physicist and astronomer. He experimented with the pendulum, the thermometer, the telescope. He was professor of mathematics at Pisa. His discoveries in astronomy resulted in his coming into conflict with the church; and he was, when old, summoned to Rome and made to abjure the Copernican hypothesis.

27 : 7. **Sir Francis Bacon** (1561–1626). The celebrated English philosopher, jurist, and statesman. He has often been called the Father of Modern Experimental Philosophy and Science. Though he made no important discoveries himself, the methods he adopted and discussed have since his time been amply vindicated.

27 : 11. **Wallis**, John (1616–1703). An English mathematician, grammarian, logician, and theological writer.

27 : 14. **Wilkins**, John (1614–1672). An English divine and scientist, Bishop of Chester. He was chiefly famous for his teaching of the Copernican System.

27 : 20. **Charles the Second.** King of England from 1660 to 1685. He came to the throne after the death of Cromwell and the break-up of the Republican Commonwealth. He was one of the weakest of the English kings, and it was largely owing to his vacillation and the bigotry of his brother, afterwards James II, that the Stuart line ended with the latter, and William was invited to take the throne which James II vacated, 1689.

28 : 3. **Chelsea College.** Chelsea is a district about three miles southwest of St. Paul's on the Thames River.

28 : 21. **Newton,** Sir Isaac (1642–1727). A famous English mathematician and scientist. He became a fellow of the Royal Society in 1672, and in 1703 president. The entire *Principia* was published in 1687. In it he gave to the world his mathematical theory of gravitation. The hypothesis in brief is that the attraction of the sun upon the planets varies inversely as the squares of their distances.

29 : 19. **Vesalius,** Andreas (1514–1564). A noted Belgian anatomist. — **Harvey,** William (1578–1657). A celebrated English physician, physiologist, and anatomist, and the discoverer of the double circulation of the blood.

30 : 7. **Schoolmen.** The mediæval philosophers who spent their time discussing the most distressingly abstruse problems, the nature of the ideal and the real, the finite and infinite; how many angels could dance on the tip of a needle, and whether a donkey set midway between two haystacks would not, because of indecision, fall dead of starvation, — these were a few of the speculations, together with the interesting question of turning baser metals into gold.

32 : 5. **Hooke**, Robert (1635–1703). An English mathematician and physicist.

32 : 23. **Boyle**, Robert (1627–1691). A British chemist and natural philosopher. He is best known as the discoverer of Boyle's law of the elasticity of air, and is the founder of Boyle's *Lectures for the Defence of Christianity*.

32 : 24. **Evelyn**, John (1620–1706). He was a member of the Royal Society, but is chiefly known to us by his interesting series of letters and his diary.

33 : 4. **Restoration**. The restoration to the English throne of Charles II, after the Commonwealth, 1660.

37 : 7. **According to them . . . of men.** The following from Huxley's essay on the *Progress of Science* is interesting in this connection: —

"In fact, the history of physical science teaches, and we cannot too carefully take the lesson to heart, that the practical advantages, attainable through its agency, never have been, and never will be, sufficiently attractive to men inspired by the inborn genius of the interpreter of Nature, to give them courage to undergo the toils and make the sacrifices which that calling requires from its votaries. That which stirs their pulses is the love of knowledge and the joy of the discovery of the causes of things sung by the old poet — the supreme delight of extending the realm of law and order ever farther towards the unattainable goals of the infinitely great and the infinitely small, between which our little race of life is run. In the course of this work, the physical philosopher, sometimes intentionally, much more

often unintentionally, lights upon something which proves to be of practical value. Great is the rejoicing of those who are benefited thereby; and, for the moment, science is the Diana of all the craftsmen. But, even while the cries of jubilation resound and this flotsam and jetsam of the tide of investigation is being turned into the wages of workmen and the wealth of capitalists, the crest of the wave of scientific investigation is far away on its course over the illimitable ocean of the unknown.

"Far be it from me to depreciate the value of the gifts of science to practical life, or to cast a doubt upon the propriety of the course of action of those who follow science in the hope of finding wealth alongside truth, or even wealth alone. Such a profession is as respectable as any other. And quite as little do I desire to ignore the fact that, if industry owes a heavy debt to science, it has largely repaid the loan by the important aid which it has, in its turn, rendered to the advancement of science. In considering the causes which hindered the progress of physical knowledge in the schools of Athens and of Alexandria, it has often struck me that where the Greeks did wonders was in just those branches of science, such as geometry, astronomy, and anatomy, which are susceptible of very considerable development without any, or any but the simplest, appliances. It is a curious speculation to think what would have become of modern physical science if glass and alcohol had not been easily obtainable; and if the gradual perfection of mechanical skill for industrial ends had not enabled investigators to obtain, at comparatively little cost, microscopes, telescopes,

and all the exquisitely delicate apparatus for determining weight and measure and for estimating the lapse of time with exactness, which they now command. If science has rendered the colossal development of modern industry possible, beyond a doubt industry has done no less for modern physics and chemistry, and for a great deal of modern biology. And as the captains of industry have, at last, begun to be aware that the condition of success in that warfare, under the forms of peace, which is known as industrial competition, lies in the discipline of the troops and the use of arms of precision, just as much as it does in the warfare which is called war, their demand for that discipline, which is technical education, is reacting upon science in a manner which will, assuredly, stimulate its future growth to an incalculable extent. It has become obvious that the interests of science and of industry are identical; that science cannot make a step forward without, sooner or later, opening up new channels for industry; and, on the other hand, that every advance of industry facilitates those experimental investigations, upon which the growth of science depends. We may hope that, at last, the weary misunderstanding between the practical men who professed to despise science, and the high and dry philosophers who professed to despise practical results, is at an end.

"Nevertheless, that which is true of the infancy of physical science in the Greek world, that which is true of its adolescence in the seventeenth and eighteenth centuries, remains true of its riper age in these latter days of the nineteenth

century. The great steps in its progress have been made, are made, and will be made, by men who seek knowledge simply because they crave for it. They have their weaknesses, their follies, their vanities, and their rivalries, like the rest of the world; but, whatever by-ends may mar their dignity and impede their usefulness, this chief end redeems them. Nothing great in science has ever been done by men, whatever their powers, in whom the divine afflatus of the truth-seeker was wanting. Men of moderate capacity have done great things because it animated them; and men of great natural gifts have failed, absolutely or relatively, because they lacked this one thing needful."

37 : 14. **Aladdin.** The hero of the Arabian story, *Aladdin and the Wonderful Lamp,* in the *Thousand Nights and One Night.* By rubbing the lamp the hero summoned a powerful spirit to his aid, who built him a palace, got for him the most beautiful bride in the world, and made him the most fortunate and happy prince in the universe.

40 : 6. **"When in heaven . . . heart."** From a specimen of a translation of the *Iliad,* in blank verse, by Tennyson. — *Iliad,* VIII, 542–561.

41 : 9. **Fetish.** The earliest form of polytheistic worship. In this some object, carved to represent the spirit of a dead member of the tribe, or some natural object that suggests him, is set up and worshipped, with offerings to propitiate his favor, or to request for the tribe his strength.

42 : 12. **"Increasing God's honour . . . estate."** Part of Bacon's statement of his purpose in writing the *Advancement of Learning.*

44 : 8. **Discovery of oxygen.** Discovered by Priestley in 1774.

44 : 18. **Count Rumford.** Thompson, Benjamin (1753–1814). An American scientist who spent most of his life in Europe and England. He was a member of the Royal Society, but most of his time was spent in politics and administration.

45 : 22. **Modifications of life.** A reference to the Darwinian hypothesis.

46 : 16. **Fetishism.** See page 306.

46 : 17. **Polytheism.** A religion which finds in the universe many gods, each with his peculiar duties and attributes. In its earliest forms it is a pure worship of the powers of nature. Gradually these powers became personified and their functions and characters distinctly marked. Along with this came the worship of ancestors and departed heroes, who became identified with the personified powers of nature. This was especially true of the religion of India and perhaps of Greece. — **Theism.** The worship of one infinite and all-powerful transcendent and immanent Deity, possessing personal characteristics and working for righteousness. Mohammedanism, Judaism, and Christianity are its chief world-forms. — **Atheism.** The denial of any God in the theistic sense of the word. It substitutes for the personal deity some blind force of nature. It is usually associated with materialism, the denial of the spirit, and the spiritual in nature, for which it substitutes matter, or force, and its laws of operation.

46 : 18. **Rationalism.** The doctrine that would deny the

presence of any power in nature that works at times contrary to nature and its laws, as they are interpreted by the rational faculties of the mind.

47 : 6. **Unknown.** A reference to Acts xvii. 23. The Apostle Paul, on his visit to Athens, saw an altar erected to the *Unknown God;* upon this he based his sermon to the Athenians.

50 : 2. **Verification.** Huxley defines the position of the man of science in his essay, "Possibilities and Impossibilities," *Coll. Essays*, Vol. V, 192, as follows: "When it is rightly stated, the Agnostic view of 'miracles' is, in my judgment, unassailable. We are not justified in the *a priori* assertion that the order of nature, as experience has revealed it to us, cannot change. In arguing about the miraculous, the assumption is illegitimate, because it involves the whole point in dispute. Furthermore, it is an assumption which takes us beyond the range of our faculties. Obviously, no amount of past experience can warrant us in anything more than a correspondingly strong expectation for the present and future. We find, practically, that expectations, based upon careful observations of past events, are, as a rule, trustworthy. We should be foolish indeed not to follow the only guide we have through life. But, for all that, our highest and surest generalisations remain on the level of justifiable expectations; that is, very high probabilities. For my part, I am unable to conceive of an intelligence shaped on the model of that of men, however superior it might be, which could be any better off than our own in this respect, that is, which could possess logically justifiable grounds for

certainty about the constancy of the order of things, and therefore be in position to declare that such and such events are impossible. Some of the old mythologies recognised this clearly enough. Beyond and above Zeus and Odin there lay the unknown and inscrutable Fate, which, one day or other, would crumple up them and the world they ruled to give place to a new order of things.

"I sincerely hope that I shall not be accused of Pyrrhonism, or of any desire to weaken the foundations of rational certainty. I have merely desired to point out that rational certainty is one thing, and talk about 'impossibilities' or 'violation of natural laws' another. Rational certainty rests upon two grounds: the one that the evidence in favour of a given statement is as good as it can be; the other, that such evidence is plainly insufficient. In the former case, the statement is to be taken as true, in the latter as untrue, until something arises to modify the verdict, which, however properly reached, may always be more or less wrong, the best information being never complete, and the best reasoning being liable to fallacy.

"To quarrel with the uncertainty that besets us in intellectual affairs would be about as reasonable as to object to live one's life, with due thought for the morrow, because no man can be sure he will be alive for an hour hence. Such are the conditions imposed upon us by nature, and we have to make the best of them. And I think that the greatest mistake those of us who are interested in the progress of free thought can make is to overlook these limitations, and to deck ourselves with the dogmatic feathers which are the

traditional adornment of our opponents. Let us be content with rational certainty, leaving irrational certainties to those who like to muddle their minds with them."

A LIBERAL EDUCATION, AND WHERE TO FIND IT

An address to the South London Workingmen's College, delivered on the 4th of January, 1868, and subsequently published in *Macmillan's Magazine*. Huxley was all his life interested in the subject of education. In 1865 he was one of those interested in the founding of the International Educational Society, the object of which was to encourage the teaching of physical and social sciences and modern languages, all of which subjects were at that time sadly neglected in the schools and universities. In 1869, he spoke on scientific education at Liverpool. In 1870–1871 he was on the London School Board.

52 : 18. **Ichabod**. A Hebrew expression, meaning the glory has departed from us.

55 : 11. **Senior wranglership**. Highest honors in the Cambridge University final examination in mathematics. — **Double-first**. Highest honors in the Oxford University final examinations in classics or mathematics.

58 : 2. **Gambit**. In chess an opening in which a pawn or a piece is sacrificed in order to secure an advantageous position.

58 : 4. **Check**. The exposure of a king to a direct attack of an opposing piece.

58 : 8. **Suppose . . . knight.** Huxley uses this same idea of a game in a letter to Charles Kingsley in 1863. "This universe is, I conceive, like to a great game being played out, and we poor mortals are allowed to take a hand. By great fortune the wiser among us have made out some few of the rules of the game, as at present played. We call them 'Laws of Nature,' and honour them because we find that if we obey them we win something for our pains. The cards are our theories and hypotheses, the tricks our experimental verifications. But what sane man would endeavour to solve this problem: given the rules of a game and the winnings, to find whether the cards are made of pasteboard or goldleaf? Yet the problem of the metaphysicians is to my mind no saner." — *Life and Letters*, Vol. I, p. 262.

59 : 6. **Retzsch, Moritz** (1779–1857). A German etcher and painter. He illustrated works of Goethe, Schiller, etc.

59 : 19. **Harmony with those laws.** In a letter to Charles Kingsley in 1860, Huxley wrote: "The more I know intimately of the lives of other men (to say nothing of my own), the more obvious it is to me that the wicked does not flourish nor is the righteous punished. But for this to be clear we must bear in mind what almost all forget that the rewards of life are contingent upon obedience to the whole law — physical as well as moral — and that moral obedience will not atone for physical sin, or *vice versa*.

"The ledger of the Almighty is strictly kept, and every one of us has the balance of his operations paid over to him at the end of every minute of his existence.

"Life cannot exist without a certain conformity to the

surrounding universe — that conformity involves a certain amount of happiness in excess of pain. In short, as we live we are paid for living.

"And it is to be recollected in view of the apparent discrepancy between men's acts and their rewards that Nature is juster than we. She takes into account what a man brings with him into the world, which human justice cannot do. If I, born a bloodthirsty and savage brute, inheriting these qualities from others, kill you, my fellow-men will very justly hang me, but I shall not be visited with the horrible remorse which would be my real punishment if, my nature being higher, I had done the same thing." — *Life and Letters*, Vol. I, p. 236.

61 : 18. **Test-acts.** A series of Acts passed by the English Parliament, which were aimed at excluding Catholics from places in the government and in the universities. The first one was passed in 1563.

61 : 23. "**Poll.**" Cambridge university slang. The students who content themselves with the pass-course, without attempting one of the honor-courses. The word is from the Greek *πολλοί*, 'many,' plural of *πολύς*.

64 : 10. **Negative answer.** The reader must remember that this referred to the England of nearly fifty years ago. Since that time conditions have been much changed owing largely to Huxley's efforts.

65 : 8. **Hundred.** Roughly equivalent to our township.

66 : 2. "**The halfpenny . . . sack.**" From *I Henry IV*, II, 4, 592. Sack was an old sweetened wine; it was a favorite drink with old Sir John Falstaff.

67 : 14. **"With a circumbendibus."** In a roundabout way.

71 : 15. **Euclid**. Euclid's geometry. Euclid (about 300 B.C.), the great Alexandrian geometrician, wrote a treatise which still is used as a text-book in many English schools.

72 : 4. **History**. Of teaching history, Huxley writes to his son, "I believe that history might be and ought to be taught in a new fashion so as to make the meaning of it as a process of evolution intelligible to the young."

72 : 10. **Public schools**. Not what we mean by public schools in this country, but the large boarding-schools, — Rugby, Eton, Harrow.

72 : 15. **Revolution in 1688**. The Stuart kings had gone from bad to worse. Charles II, though personally not unpopular, was considered dangerous to the great mass of thinking English because of his secret leanings to Catholicism, and because of his open subservience to the French king, Louis XIV. His brother, James II (1685–1688), was a gloomy, stern man, who was not only openly a Catholic but also a tyrant and an upholder of the old "divine-right doctrine." His rule was endured, however, until a prince was born to him, and then, the people seeing that the Stuart policy was likely to continue unless drastic measures were undertaken, invited William of Orange and his wife Mary, sister of James, over to recover English liberties. James fled from England, and William and Mary were crowned king and queen.

72 : 16. **France . . . in 1789**. The great French Revolution, when the king, Louis XVI, was beheaded, and a republic, patterned somewhat on that of America, set up. In France

it was the middle and lower classes that led in the revolution, and its excesses, painted so vividly in Victor Hugo's *Ninety-Three* and Dickens's *Tale of Two Cities*, were committed by the lowest; in England the revolution of 1688 was accomplished by the highest classes, the lower concurring silently. The differences between the two nationalities is well brought out in these two political upheavals.

72 : 17. **Chaucer** (1340–1400). Besides being one of the greatest of English poets, and the author of the *Canterbury Tales*, Chaucer is famous for his having done much to fix the form of literary English, and to teach Englishmen that their language had artistic possibilities. — **Shakspeare** (1564–1816). Any further reference to this great dramatist is unnecessary. — **Milton**. See page 300. — **Voltaire**. The assumed name of François Marie Aroult (1694–1778). It is impossible to give in a note a list of the plays and other writings of this versatile Frenchman. He was a literary lion, the leader in thought of his age.

72 : 18. **Goethe**, Johann Wolfgang von (1749–1832). It is as hard to give a hint of the greatness of this German writer as it is to note Shakespeare and Voltaire. He is the author of *Faust*, a leader in literature and thought; and every year his leadership takes a more and more certain hold. — **Schiller**, Johann Christoph Friedrich von (1750–1805). The only German writer who disputes Goethe's commanding influence. His *Wilhelm Tell*, *Maria Stuart*, and *Jungfrau von Orleans*, are familiar to all students of German.

75 : 2. **Crœsus**. A king of Lydia, about 550 B.C. The wealthy king to whom the wise Solon is said to have

remarked, when shown the great treasures, "Account no man happy before his death." He was conquered by the Persians.

77 : 14. **Niebuhr**, Barthold Georg (1776–1831). A celebrated German scholar, historian, and critic. — **Gibbon,** Edward (1737–1794). The historian who wrote the first really scientific history in English, *The Decline and Fall of the Roman Empire*. — **Grote**, George (1794–1871). The author of the celebrated *History of Greece*.

78 : 20. **Pedantic in its terminology**. Huxley wished to make his elementary courses in science, observations of the commonest facts from which pupils would be led to general scientific truths. He wished the instruction to be simple, for the youthful mind "loathes everything in the shape of long words and abstract notions, and small blame to it." Sometimes in our science courses now we are not so careful in this as we might be.

79 : 14. **Cicero**, Marcus Tullius (106–43 B.C.). The Roman writer, critic, and orator. His works are studied because they exhibit the purest classical Latin. — **Horace**, Quintus Horatius Flaccus (65–8 B.C.). The most finished Latin lyricist.

79 : 15. **Sixth form**. Our last year of high school.

79 : 15. **Terence**. Publius Terentius Afer (185–159 B.C.). The greatest Latin writer of comedy.

80 : 8. **Parnassus**. A mountain ridge in Greece, the fabled abode of the Muses, Apollo, and the nymphs, hence the haunt of poetry and learning.

80 : 17. **But if . . . schools**. Huxley, as one can see,

did not wish to discard a classical education. He only felt that culture could be gained without a training in the classics. "Culture of former periods might be purely literary, that of to-day must be based, to a great extent, upon natural science." — *Coll. Essays*, Vol. III, 104.

81 : 12. **These be your gods, O Israel!** The expression used by Jeroboam, King of Israel, when he persuaded his followers to worship the golden calves instead of the one God.

82 : 3. **Rector of Lincoln College.** Mark Pattison (1813–1884). An English writer, especially noted to-day as a commentator on Milton.

85 : 23. **Mill**, John Stuart (1806–1873). The English philosophical writer, logician, and economist. In many ways he belonged to the same school of thinkers as Huxley. — **Faraday**, Michael (1791–1867). An English chemist and electrician. His discoveries in electricity were of the greatest importance — especially that of magneto-electric induction.

85 : 24. **Robert Brown** (1773–1858). An English botanist. — **Lyell**, Sir Charles (1797–1875). The English geologist. Huxley was closely associated with him in his study of fossils. — **Darwin**, Charles Robert (1809–1882). The man whose name is chiefly associated with the theory of evolution. His *Origin of Species* has been mentioned in the note on page 296.

88 : 8. **"La carrière ouverte aux talents."** The career belongs to the man with talent.

88 : 9. **Bursch.** A student at a German university.

89 : 12. **But until . . . schools.** Huxley had high ideals

for a true university. Read the following from his *Universities Actual and Ideal.* "In an ideal University, as I conceive it, a man should be able to obtain instruction in all forms of knowledge, and discipline in the use of all the methods by which knowledge is obtained. In such a University the force of living example should fire the student with a noble ambition to emulate the learning of learned men, and to follow in the footsteps of the explorers of new fields of knowledge. And the very air he breathes should be charged with that enthusiasm for truth, that fanaticism of veracity, which is a greater possession than much learning, a nobler gift than the power of increasing knowledge; by so much greater and nobler than these, as the moral nature of man is greater than the intellectual; for veracity is the heart of morality."

"It has been my fate," commented Huxley, on his visit to Johns Hopkins University in Baltimore, "to see great educational funds fossilise into mere bricks and mortar in the petrifying springs of architecture, with nothing left to work them. A great warrior is said to have made a desert and called it peace. Trustees have sometimes made a palace and called it a university."

91 : 11. There is scope enough . . . language alone. The following appeared in the *Pall Mall Gazette* of October 22, 1891: "I fully agree with you that the relation of our universities to the study of English literature is a matter of great public importance; and I have more than once taken occasion to express my conviction: Firstly, that the works of our great English writers are preëminently worthy of

being systematically studied in our schools and universities as literature; and secondly, that the establishment of professional chairs of philology, under the name of literature, may be a profit to science, but is really a fraud practised upon letters."

As an epilogue to this lecture, the two following extracts are interesting. The first is from a letter to Professor Lankester, April 11, 1892; the second is an extract from his own miscellaneous writings of the same year.

(1) "The mediæval university looked backwards: it professed to be a storehouse of old knowledge, and except in the way of dialectic cobweb-spinning, its professors had nothing to do with novelties. Of the historical and physical (natural) sciences, of criticism and laboratory practice, it knew nothing. Oral teaching was of supreme importance on account of the cost and rarity of manuscripts.

"The modern university looks forward, and is a factory of new knowledge; its professors have to be at the top of the wave of progress. Research and criticism must be the breath of their nostrils; laboratory work the main business of the scientific student; books his main helpers." — *Life and Letters*, Vol. II, 328.

(2) "The cardinal fact in the university question appears to me to be this: that the student to whose wants the mediæval university was adjusted, looked to the past and sought book-learning, while the modern looks to the future and seeks the knowledge of things.

"The mediæval view was that all knowledge worth having was explicitly or implicitly contained in various

ancient writings: in the Scriptures, in the writings of the greater Greeks, and those of the Christian Fathers. Whatever apparent novelty they put forward, was professedly obtained by deduction from ancient data.

"The modern knows that the only source of real knowledge lies in the application of scientific methods of inquiry to the ascertainment of the facts of existence; that the ascertainable is infinitely greater than the ascertained, and that the chief business of the teacher is not so much to make scholars as to train pioneers." — *Life and Letters*, Vol. II, p. 329.

ON A PIECE OF CHALK

Delivered at the Norwich meeting af the British Association for the Advancement of Science, 1868. This lecture illustrates what Huxley said in his lecture on the "Educational Value of Natural History Sciences" — "Science is nothing but trained and organized common sense."

The lecture should be read with frequent reference to an atlas.

104 : 16. **Ehrenberg**, Christian Gottfried (1795–1876). A German naturalist, noted for his study of *infusoria*, minute water plants, and animals.

105 : 10. **Shipmate of mine.** A reference to the voyage which Huxley took in the Rattlesnake. See *Autobiography*.

117 : 7. **Sir Charles Lyell.** See note on page 316.

117 : 21. **Echinus.** The sea-urchin.

117 : 22. **"The upper valve . . . mud."** *Elements of Geology*, Lyell, p. 23.

121 : 18. **Drift, or boulder clay.** The materials brought down by glaciers.

125 : 8. **Euphrates and Hiddekel.** See Genesis ii. 14.

125 : 20. "**The great river, the river of Babylon.**" See Genesis xv. 18.

126 : 16. **Sinai.** A range of mountains in northwestern Arabia, near the Gulf of Suez. — **Ararat.** A high mountain range in Armenia.

128 : 7. **Australia.** The fauna of Australia has many peculiarities: the kangaroo, the duck-bill, ornithorhynchus, etc. The American opossum is the only remnant of the pouch-bearing animals in America.

129 : 11. **Pterodactyl,** etc. See a good dictionary, such as Webster's International or the Century, for pictures of these strange monsters.

130 : 20. **Battle of Hastings** (1066). Fought between the Saxons under Harold, and the Normans under William, for the mastery of England. The Normans conquered, and a line of Norman kings began to reign in England.

135 : 12. "**Without haste, but without rest.**" Goethe's motto adopted by Huxley in his early days, "*Wie das Gestern, Ohne Hast, Ohne Rast,* " Like the star, without haste, without rest."

ON THE EDUCATIONAL VALUE OF THE NATURAL HISTORY SCIENCES

An address delivered at St. Martin's Hall, on the 22d of July, 1854, and published as a pamphlet in that year. In the course of his prefatory letter to the volume of Lay

Sermons, addressed to Professor Tyndall, Huxley says of this lecture that it "Contains a view of the nature of the differences between living and not living bodies out of which I have long since grown."

138 : 4. **Newton**. See note, page 302.

140 : 3. **Infusoria**. The numerous animalcula that occur in an infusion of decaying vegetable or animal matter.

144 : 14. **Inquisition**, or the Holy Office, an ecclesiastical court for the detection and punishment of heresy.

145 : 11. **Cuvier**, Baron Georges Léopold Chrétien Frédéric Dagobert (1769–1832). The Frenchman who laid the foundation of the modern science of comparative anatomy.

145 : 17. **Adams**, John Couch (1819–1892). An English astronomer who shares with Leverrier the honor of discovering the planet Neptune (1846). — **Leverrier**, Urbain Jean Joseph (1811–1877). The French astronomer, who, working independently, discovered the planet Neptune at about the same time as the Englishman, Adams.

146 : 3. **M. Jourdain**. The hero of Molière's *Le Bourgeois Gentilhomme*. The story of how he suddenly learned that he had been talking in prose all his life has become a proverb.

147 : 7. **Annulose**. Ringed. Composed of rings, like some worms.

147 : 10. **Euclid**. See note on page 313.

148 : 6. **Comparative Anatomy**. That part of biological science which compares the organs and the functions of different forms of life, and thus classifies them according to their degrees of similarity.

149 : 1. **Harvey**. See note on page 302.

149 : 3. **Sir Charles Bell** (1774–1842). The physiologist who discovered the functions of the sensory and motor nerves.

149 : 20. **Bernard,** Claude (1813–1878). A French physiologist.

150 : 7. **Rosaceæ.** The rose family of plants. A large family including many of our familiar fruit trees.

156 : 2. **Ascidians.** A class of small sea animals, intermediate between the molluscs and the vertebrates. The young are tadpole-like, and free-swimming, but when older, they attach themselves to fixed objects. The shape is a little like a double-necked bottle.

157 : 8. **Laplace,** Marquis Pierre Simon de (1749–1827). The famous French astronomer and mathematician.

157 : 9. **Jardin des Plantes.** The Botanical Gardens. — **Cuvier.** See note on page 321.

159 : 14. "**To point a moral or adorn a tale.**" From Dr. Johnson's *Vanity of Human Wishes.*

162 : 17. **And that not long ago . . . Satan.** Huxley did a little experimenting with spiritualistic phenomena. An account of a séance is found in his *Life and Letters,* Vol. I, pp. 452–455. It is needless to say that he remained unconvinced of their genuineness.

164 : 7. **Manichean doctrine.** A heresy which crept into the Christian church in the fourth century, which regarded all pleasure as sinful and set the most vigorous laws against any indulgence.

164 : 21. "**A primrose . . . more.**" From Wordsworth's *Peter Bell.*

165 : 16. **Florentine,** Dante. The reference is to Canto VII of the *Inferno,* the punishment of the sullen who were immersed in mud. — **Dante,** Alighieri (1265–1321), in his *Divine Comedy,* describes his journey through the three great regions of departed spirits, Hell, Purgatory, and Paradise. In these he found them punished according to the degree of wickedness of their deeds, expiating the wickedness which they had repented, or enjoying the rewards of their virtues.

It is not necessary to supplement these notes with further extracts from Huxley's writings to prove his idea of the educational value of the sciences and of the science of biology in particular. This has been done in his *Autobiography* and his lecture on *The Advisableness of Improving Natural Knowledge,* and *A Liberal Education.*

A LOBSTER; OR, THE STUDY OF ZOÖLOGY

A lecture delivered in 1861 to teachers at the South Kensington Museum. This lecture is interesting for the clear way in which Huxley handles a rather complicated subject in zoölogy. The plea for scientific teaching in the latter part of the lecture, from page 191 on, sounds rather strange to us to-day when scientific courses of study and well-equipped laboratories for individual demonstration are the expected thing in all of our schools, and when our teachers, even of the purely literary branches, are expected to have had some instruction in science and the scientific method. But it must be remembered, as was pointed out in the Introduction, that in 1860 there were not in all Europe

a dozen university professors of pure science, and absolutely no teachers of science in any of the secondary schools. These facts are hard for us to appreciate to-day.

The lecture as a whole is so clear that few if any notes are needed. The reader should have before him a good picture of a lobster, the subject of the demonstration. If he be scientifically inclined, he can even procure a specimen and study its parts according to the directions given. A much better and more scientific, and perhaps for that reason more interesting, examination of a zoölogical type will be found in Huxley's study of the crayfish. Its interest, however, is more purely scientific than literary, and for that reason, and also on account of its length, it is not included in this volume.

168 : 10. **Linnæus.** See note on page 292.

172 : 9. **The final object . . . matter.** This is explained by Huxley himself on page 190.

183 : 9. **And so . . . geologist.** "The different grouping necessitated by later knowledge does not affect the principle of the argument." (Huxley's note in 1894.)

189 : 22. **A disturbance of the electrical state of their molecules.** The causes of the disturbance of the molecules in the brain and their modes of action preceding and during a nervous stimulus are as much a secret as ever. The idea that they are similar to a number of electrical batteries ready to send discharges along the nerve-fibres serves as a good analogy; and even if it be accepted as an explanation, it still leaves us as much in the dark as ever as to how disturbances of microscopic cells in the brain can be converted into the muscular energy which may be exerted by the arm or leg.

ON DESCARTES' "DISCOURSE TOUCHING THE METHOD OF USING ONE'S REASON RIGHTLY AND OF SEEKING SCIENTIFIC TRUTH"

An address to the Cambridge Young Men's Christian Society, delivered on the 24th of March, 1870, and subsequently published in *Macmillan's Magazine*.

209 : 7. René Descartes (1596–1650), the father of modern philosophy, as Bacon is said to be the father of modern science. The similarity between these two great men lies not so much in what they did, though Descartes in actual accomplishment ranks far ahead of Bacon, but in the impetus they gave to the really true, scientific, and philosophic method. They both taught the necessity of getting away from untested theories and hypotheses to grounded fact. In other words, both were, in general, inductive in their methods. Before they would build a superstructure by means of logic, they would test the strength of its foundation. It is needless to say that without such rigid inquiry into the nature of man and the world, modern science and modern philosophy would be impossible. It is also needless to say that both of them unconsciously were affected powerfully by the teachings of the philosophers of the times just before theirs, and in consequence much of their theorizing is to our time not only illogical, but almost ridiculous; for example, Descartes attempted to find the seat of the soul in the central gland of the brain, and made an artificial distinction between spirit and matter, both of which errors are well pointed out

by Huxley. It is the new method they adopted, and the new uses to which they put it, that renders them so important to all succeeding thinkers.

209 : 15. **Voltaire.** See note on page 314.

209 : 17. "**He expressed . . . anybody.**" "I forget who it was said of him, '*Il a plus que personne l'esprit que tout le monde a*'" [He has more than anybody the genius that everybody has] (Huxley's note).

210 : 5. **Jesuits.** An order in the Catholic Church founded by Ignatius Loyola (1491-1556) and others for the purpose of spreading the Catholic faith, crushing heresy, and educating the youth.

210 : 12. "**Discourse.**" "*Discours de la Methode pour bien conduire sa Raison et chercher la Verité dans les Sciences.*" (See title of this essay) (Huxley's note).

212 : 24. "**The active . . . conquer itself.**" "*Eine thätige skepsis ist die, welche unablässig bemüht ist sich selbst zu uberwinden, und durch geregelte Erfahrung zu einer Art von bedingter Zuverlässigkeit zu gelangen*" [An active scepticism is one which ceaselessly strives to conquer itself, and through regulated experience to reach a sort of conditional certainty]. *Maximen und Reflexionen*, 7te Abtheilung (Huxley's note).

213 : 18. **Une morale par provision.** A provisional morality, a provisional self-government.

221 : 13. **Cartesian philosophy.** Philosophy of Descartes and his school. In no treatment of the history of philosophy is the relativity of our knowledge of the outside world or of ourselves better expressed than in the foregoing pages

A new world of thought is here opened up for the young student.

221 : 24. **Bach**. The name of a famous family of musicians. The reference here is probably to Sebastian (1685–1750), the composer of piano music. Huxley tells us: "When I was a boy, I was very fond of music, and I am so now; and it so happened that I had the opportunity of hearing much good music. Among other things, I had abundant opportunities of hearing that great old master, Bach. I remember perfectly well — although I knew nothing about music then, and, I may add, know nothing whatever about it now — the intense satisfaction and delight which I had in listening, by the hour together, to Bach's fugues. It is a pleasure which remains with me, I am glad to think; but, of late years, I have tried to find out the why and wherefore, and it has often occurred to me that the pleasure derived from musical compositions of this kind is essentially of the same nature as that which is derived from pursuits which are commonly regarded as purely intellectual. I mean, that the source of pleasure is exactly the same as in most of my problems in morphology — that you have the theme in one of the old master's works followed out in all its endless variations, always appearing and always reminding you of unity in variety."

222 : 9. **Kant**, Immanuel (1724–1804). A famous German philosopher. His *Critique of Pure Reason* marked an epoch in modern philosophy. He taught that the mind has three great laws (categories, as he called them) according to which it interprets the sensations that are

presented to it, those of time, space, cause, and effect. These three things which we seem to find in nature we really construct in our own consciousness. They give us no real knowledge of the external objects, if any, which are the cause of these phenomena. This is Kant's *Critical Idealism*. In his *Critique of Practical Reason* he restored the outer world, God, freedom, and immortality, which he said are necessary for our practical lives, for no man can live for one moment in this world if he practically doubts the reality and importance of these four things for which the *Critical Idealism* can find no philosophical and logical proof.

222 : 18. **Berkeley**, George (1685–1753). An English bishop and philosopher. He taught that there is no such thing as matter, or outside world, as we generally conceive it, nothing but spirit; that each man by means of his consciousness (spirit) constructs in his own mind a picture of an apparent outside world.

223 : 1. "**Absolute.**" A term used by a German school of philosophers, by which our Emerson was influenced, who, starting with Kant's *Critique of Practical Reason*, built up a splendid metaphysical theory which regarded the Absolute, the Infinite, or God, as the supreme universal spirit, which manifests itself in nature and in man, gradually evolving a huge world order, the lower strata of which (stocks and stones) as yet show none or few signs of life; higher up there is life and consciousness, which in man rises to self-consciousness and the ability to reason.

As all such theorizing, beautiful and poetic as it must

appear, has no unassailable logical basis in experience, Huxley rejected it, and confined himself simply to the world of fact as he saw it, and refused to commit himself one way or other to what lay beyond. This is Huxley's agnosticism, his "I don't know" philosophy.

224 : 2. **Galileo**. See note on page 301.

224 : 14. **Schoolmen**. See note on page 302.

224 : 22. **Harvey**. See note on page 302.

225 : 13. **According to law**. "*Au milieu de toutes ses erreurs, il ne faut pas méconnaître une grande idée, qui consiste à avoir tenté pour la première fois de remener tous les phénomènes naturels à n'être qu'un simple dévelloppement des lois de la mécanique* [In the midst of all his [Descartes] errors, it is necessary not to forget one grand idea, namely, to have attempted for the first time to regard all natural phenomena as nothing but a simple development of the laws of mechanics] is the weighty judgment of Biot, cited by Bouillier" (*Histoire de la Philosophie Cartésienne*, Vol. I, p. 196) (Huxley's note).

228 : 13. "**The external . . . their movements.**" *Traité de l'Homme* (Cousin's Edition), p. 347 (Huxley's note).

228 : 28. **Real man**. "Descartes pretends that he does not apply his views to the human body, but only to an imaginary machine, which, if it could be constructed, would do all that the human body does; throwing a sop to Cerberus unworthily; and uselessly, because Cerberus was by no means stupid enough to swallow it." (Huxley's note). Descartes did not deceive the heresy hunters by this little side play.

229 : 3. "**All the functions . . . bodies.**" *Traité de l'Homme*, p. 427 (Huxley's note).

230 : 24. **Consider what . . . eye.** Compare *Traité des Passions*, Arts. XIII and XVI (Huxley's note).

233 : 12. **If the act . . . impossibility.** Compare learning to walk, skate, write, read, multiply.

233 : 17. **Chose pensante.** The thinking substance.

233 : 20. **Pineal gland.** Modern physiologists know nothing of the location of the soul. The pineal gland is in the centre of the brain.

234 : 20. **Animal spirits.** This vague creation of Descartes' fancy is not mentioned in any modern text-books of physiology or psychology.

235 : 1. **Centres of force.** Read an extremely interesting book, the *New Knowledge*, by Duncan. In it we learn that the latest theory regarding matter is that it consists of an infinite number of minute vortices, "centres of force" (the atoms), which, by their combinations, produce the molecules which go to make up what we call the visible and tangible universe.

235 : 17. **Hume,** David (1711–1776). The great Scotch philosopher who first proved that all knowledge of the inner as well as of the outer world is but a knowledge of the states of consciousness, and not of the world itself. All such things as the relation of cause and effect, which we see in the outer world, are in reality created in the consciousness. Thus he may be said to be the first of the great modern psychologists. Huxley wrote a volume on Hume in the *English Men of Letters Series*.

235 : 19. **Priestley**, Joseph (1733–1804). Chiefly noted as the discoverer of oxygen and the founder of modern chemistry.

235 : 20. **The one leads . . . materialism.** "Bouillier, into whose excellent *History of the Cartesian Philosophy* I had not looked when this passage was written, says, very justly, that Descartes, '*a merite le titre de pire de la physique, aussi bien que celui de la metaphysique moderne*'" [Descartes has earned the title of the father of modern physics as well as of modern metaphysics] (Huxley's note).

237 : 2. **Consciousness.** "For all the qualifications which need to be made here I refer the reader to a thorough discussion of the nature of the relation between nerve-action and consciousness to Mr. Herbert Spencer's *Principles of Psychology*" (Huxley's note). It might be interesting to a reader to follow this subject still farther in a book like Thorndike's elementary treatment of psychology, or in Mr. James' more elaborate psychology.

237 : 23. **Calvinism.** The doctrine that everything has been carefully regulated from the beginning, and that there is no such thing as freedom or spontaneity in man or in nature — the position of the extreme materialists, as Huxley would call them.

238 : 10. **I protest . . . the offer.** In this connection it is interesting to recall a remark made by the great German philosopher and writer, Lessing. He said: "If God held all truth shut in his right hand, and in his left nothing but ever restless instinct for truth, though with the condition of forever and ever erring, and should say to me, choose! I

should bow humbly to the left hand, and say, 'Father, give! Pure truth is for thee alone!'" Which attitude of mind do you admire the more?

238 : 18. **Their "grenadiers."** See page 223, line 4.

242 : 2. **Certain discourse.** Probably his lecture on the *Physical Basis of Life.*

242 : 17. **"Index."** The *Index Expurgatorius,* list of books not permitted to good Catholics.

242 : 21. **Vanini,** Lucilio (1585–1619). An Italian free thinker who was condemned to death on account of his departure from the accepted opinions of the church.

243 : 21. **Such treatment as the world thought good enough for him.** Huxley himself knew in a degree what this treatment was. Read his life in the Introduction.

244 : 8. **Living men.** Charles Darwin, for example.

244 : 21. **Dante.** See note on page 323.

245 : 3. **"Quest' è . . . si gode."**

"And this is she who's put on cross so much,
Even by them who ought to give her praise,
Giving her wrongly ill repute and blame.
But she is blessed, and she hears not this:
She, with the other prime creatures, glad
Revolves her sphere, and blessed joys herself."
— *Inferno,* VII, 90–95 (W. M. Rossetti's translation).

ON THE PHYSICAL BASIS OF LIFE

"The substance of this paper was contained in a discourse which was delivered in Edinburgh on the evening of Sunday, the 8th of November, 1868, being the first of a series

of Sunday evening addresses upon nontheological topics, instituted by the Rev. J. Cranbrook. Some phrases, which could possess only a transitory and local interest, have been omitted; instead of the newspaper report of the Archbishop of York's address, his Grace's subsequently published pamphlet 'On the Limits of Philosophical Inquiry' is quoted; and I have, here and there, endeavored to express my meaning more fully and clearly than I seem to have done in speaking — if I may judge by sundry criticisms upon what I am supposed to have said, which have appeared. But in substance, and, so far as my recollection serves, in form, what is here written corresponds with what was there said" (Huxley's note).

247 : 14. **Ovoid particle.** The appearance and habits of this parasite of the fly is described by Huxley in his lectures on "Spontaneous Generation," *Lay Sermons*, p. 371.

247: 20. **Indian fig.** The banyan tree.

248 : 9. **Schoolmen.** See note on page 302.

249 : 13. **Goethe.** See note on page 314.

249 : 19. "**Warum treibt . . . auch will.**" Why do people trouble themselves and shout so? They wish to feed themselves, beget children, and raise them as well as possible. More than this no man can do, let him make what effort he will. From Goethe's *Venetianische Epigramme*.

254 : 2. **Algæ.** Known chiefly to the unscientific in the form of sea and fresh water weeds. — **Fungi.** One of the lowest forms of plant life. They range in size from the unicellular yeast plant to the mushroom and toadstool.

254 : 18. **Milne-Edwards,** Henri (1800–1885). A French naturalist.

263 : 19. **Is it . . . we know?** This is the theory of the English scientist Needham. Huxley further elucidates this theory in his "Spontaneous Generation," *Lay Sermons*, p. 355.

264 : 3. **"Debemur morti nos nostraque."** We must die, we and ours. From Horace, *Ars Poetica*, l. 63.

264 : 21. **Balzac,** Honoré de (1799–1850). One of the most famous of the modern French novelists. His novels of French life have been translated into nearly every civilized language. *La Peau de Chagrin* was published in 1830.

268 : 6. **Barmecide.** One who offers imaginary food or illusory benefits; an allusion to the story in the *Arabian Nights* of a member of the Barmecide family, a noble Persian family of Bagdad, who on occasion placed before a beggar a series of empty dishes, pretending that they contained a sumptuous repast.

269 : 9. **Thaumaturgy.** Working of miracles, here the creation of protoplasm.

269 : 12. **Unable to manufacture protoplasm.** It would need light.

269 : 24. **Plants are the . . . disperse.** There are many plants, the fungi in particular, which feed only on decaying animal or vegetable matter. The distinction which Huxley makes between animals and plants, though good in general, is still not true in all details. A more detailed differentiation is necessary.

273 : 10. **Martinus Scriblerus.** A satire written chiefly

by John Arbuthnot in 1741. Pope and Swift and other members of the Scriblerus Club were also contributors.

274 : 9. **Jacob's.** The ladder Jacob saw in his dream which reached to heaven, and on which he saw angels ascending and descending. See Genesis, xxviii. 12. The religious world to-day is not so afraid of science and its results as it was in Huxley's.

276 : 7. **Absolute.** The relativity of knowledge is best shown by Huxley in his lecture on "Descartes' Discourse," pp. 213–220. It would be well to read these pages before proceeding with the rest of this lecture.

277 : 21. **Archæus.** A director or governor. An old notion of the divinity.

278 : 16. **"New Philosophy."** The scientific school of philosophy which was at this time very active in England. It refused to be diverted from its scientific study of facts in the outer world and the facts of consciousness by any of the allurements of the transcendental speculative philosophers, who just before had been extremely active in Germany, and who had striven to go beyond fact and experience to the great principle behind fact and experience, the Absolute, the Infinite.

279 : 6. **Death of Pan.** A reference to a story that while a ship was passing the island of Crete a loud voice was heard announcing the death of Pan, the deity of the woods and shepherds; immediately then was a great cry raised by all the nymphs, fauns, satyrs, and all other lesser deities of woods, streams, and hills.

281 : 25. **"If we take . . . illusion."** From Hume's essay,

"Of the Academical or Sceptical Philosophy," in the *Inquiry concerning the Human Understanding.*

These last paragraphs give with a fair amount of clearness Huxley's position of agnosticism — the "I don't know" philosophy. It is still more clearly expressed in a letter to Charles Kingsley, *Life and Letters*, Vol. I, p. 201. It is perhaps needless to say that such a position of active scepticism is necessary for the intellectual and spiritual welfare of the human race. But it is necessary to know that it is only a step in man's intellectual and spiritual progress. It is good to cast one's eyes around and carefully scrutinize one's intellectual and spiritual make-up, if one goes about it with a desire to get at truth, as did Huxley. But to say that this is the final step is equivalent to abandoning the problem, the deepest man has to face, the why of his existence, and the why of all these states of consciousness, which we call the world of facts and the world of spirit. Perhaps the best answers to such questions are to be found in the inspired verses of some of our greatest poets, Tennyson's *In Memoriam*, Browning's *Saul,* and Wordsworth's *Verses written above Tintern Abbey.*

Of this essay Huxley wrote in 1892, "I cannot say I have ever had to complain of lack of hostile criticism, but the preceding essay has come in for more than its fair share of that commodity. It may be well, therefore, for the general reader to study, in connection with it, the first chapof the standard *Text-book of Physiology*, by Dr. Foster, making fair allowance for the rapid progress of knowledge during the last quarter of a century."

INDEX TO NOTES